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Characterisation of equilibrium in oligopoly with applications to trade and taxation

submitted by Paola Labrecciosa

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Declaration

I declare that this thesis, submitted to Trinity College for the degree of Ph.D., has not been submitted as an exercise for a degree at this or any other University and that all research contained herein is entirely my own with the exception of chapters 1, 2 and 4 which include joint works, duly acknowledged in the text. I also authorize the Library of the College to lend or copy this thesis upon request.

Dublin, 1st August 2006

Paola Labrecciosa

[Signature]
To Luchino, Nanoa and Trudy
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Executive Summary

This thesis is organized into four independent chapters.

Chapter 1 is divided into two parts: part one is concerned with the characterization of optimal penal codes in presence of a \( n \) period detection lag, where \( n \) can be thought of as minutes, hours, days, weeks, etc., depending on the particular situation at stake. The idea is that, in many cases, it is not possible for a given player to directly observe the behaviors of her/his rivals, the consequence being that cheating on an implicit agreement can be kept secret for a certain time period. This may be due to information delays and/or infrequent interaction. We extend the standard Abreu (1986) result to a setting with delays in reacting to any deviation. We show that information delays reduce cartel stability. As an illustration, we provide two examples dealing with either price or quantity competition. In the second part of the chapter, we explore the possibility that optimal penal codes may fail to be optimal. We modify one of the Abreu (1986)'s assumptions by introducing economies of scale and compare the critical discount factor implied by Abreu's penal rules with the one generated by infinite Nash reversion. We show that, when economies of scale are sufficiently strong, grim trigger strategies are more efficient in stabilizing collusion than optimal penal codes.

Chapter 2 aims at providing a contribution to the literature of intra-industry trade. The issue analyzed is the impact of economic integration on the stability of international cartels in a setting where economic integration is captured by a reduction in per unit trade costs. The motivating factor is represented by the overwhelming number of collusive agreements involving firms operating in more than one country prosecuted by the US Department of Justice and the European Commission in the 1990s combined with the industry evidence on the 1990s international cartels suggesting that they were formed as a result of increasing competition and market integration. By dealing with both quantity and price competition, we show that there exists an admissible parameter region wherein economic integration enhances cartel stability no matter firms' strategic variable.
Chapter 3 focuses on implicit collusion, commodity taxation and tariffs. The aim of the chapter is twofold: (i) to include commodity taxation in the analysis of implicit collusion; (ii) to provide new insights on the effects of tariffs on cartel stability. As to (i), the interest is to assess how the two main forms of commodity taxation, namely ad valorem and specific, affect the sustainability of implicit collusive agreements. To this end, we proceed with a comparison in terms of critical discount factors sustaining full collusion, within a standard closed economy two-firm model of quantity competition. We show that while specific taxation does not affect the stability of collusion, ad valorem taxation makes it easier or harsher for firms to collude depending on the nature of scale economies. In industries where collusion is likely and diseconomies of scale prevail, ad valorem taxation seems to be more collusion-enhancing than specific taxation, implying that specific taxation should be favored by an antitrust authority interested in fostering greater competition. As to (ii), the focus is on the impact of ad valorem and specific tariffs on collusion. As in the closed economy section, we adopt both grim trigger strategies and stick and carrots optimal punishments and derive the critical discount factors sustaining full collusion. The implicit collusive agreement consists, for each firm, in refraining from exporting into each other’s market. We show that, under grim trigger strategies, an ad valorem tariff is more collusion-enhancing than an equivalent specific tariff if and only if the revenue collected by the government through the protectionist instrument is sufficiently low, suggesting that specific tariffs are more efficient in the presence of relatively integrated markets. Under optimal punishments, an ad valorem tariff is always more collusion-enhancing than an equivalent specific tariff no matter the amount of revenue collected. These results seem in contrast with the conventional wisdom according to which ad valorem tariffs should be preferred to specific tariffs on welfare grounds.

Finally, Chapter 4 investigates how optimal corporation tax should be designed in reaction to industry specific sunk costs in long run equilibrium. We first write down a general oligopoly model to show that optimal profit taxation is negatively related to industry specific sunk costs once a degree of monopolistic power survives in long run equilibrium. We then illustrate our
point with an example considering a Cournot oligopoly game at the long run equilibrium. By focussing on the influence of corporation tax on market structure, our study shows that industries characterized by high sunk costs, which are ceteris paribus, linked to concentrated industries, should be taxed softly. On the contrary, when sunk costs are low, the opposite holds true. In our empirical section we provide suggestive evidence that this principle of taxation was used in France, Italy and the UK in the 90s.
Chapter 1

Optimal Punishments: detection lags and suboptimality\(^1\)

1.1 Introduction

The repeated game literature has traditionally considered two different kinds of punishments: Nash reversion (Friedman, 1971) and the more severe stick and carrot optimal punishments dating back to Abreu (1986; 1988). The punishment resulting as a solution to the problem stated in Abreu (1986; 1988) is optimal in the sense that, all else equal, the associated critical discount factor above which collusion is indeed stable is lower than or at most equal to any corresponding critical threshold produced by other forms of punishment, e.g., the infinite Nash reversion characterizing the Perfect Folk Theorem.

The aim of this chapter is twofold: first, we want to characterize optimal two-phase punishments in presence of a \( n \) period detection lag, i.e. when cheating on an implicit agreement can be kept secret for a certain time period. To this end, we modify both the private incentives of staying in the collusive agreement and the private incentives of adhering to the prescribed penal code accordingly. Secondly, we intend to investigate, within a Cournot supergame, whether

\(^1\)This chapter is based on a joint work with Luca Colombo (2006a, 2006b).
optimal punishments may become suboptimal when the slope of the marginal cost is different from zero, namely, when economies of scale are not negligible. To this end, we compare the traditional grim trigger strategies (Friedman, 1971) with symmetric optimal penal codes in terms of critical discount factors sustaining full collusion.

Our results can be summarized as follows: in the first part of the chapter, we show how the presence of a \( n \) period detection lag affects the derivation of optimal penal codes. We provide two simple examples in which, when deviation payoffs can be gained for an additional period, cartel stability is reduced. In the second part of the chapter, we show that for sufficiently strong increasing returns to scale, the optimal punishment drives each firm down to the security level. Furthermore, we show that for even stronger increasing returns to scale, the critical discount factor associated with grim trigger strategies is lower than the one associated with optimal penal codes, implying that Nash reversion allows firms to sustain collusion more efficiently.

### 1.2 Analytical Framework

Before proceeding with the analysis, let us provide a brief illustration of the analytical framework adopted.

**Grim trigger strategies.** Following Friedman (1971) and Fudenberg and Maskin (1986), each firm sticks to the cooperative strategy as long as the rival does likewise. If a deviation is detected, say at time \( t \), both firms revert to the one shot Nash equilibrium strategy from time \( t + 1 \) onwards. We denote by \( \pi^c \) the per-period collusive profits, by \( \pi^d \) the extra profits in period \( t \) \((t = 0)\) when the firm defects from the implicit collusive agreement, and by \( \pi^N \) the per-period punishment profits, which, in the case of grim trigger strategies, correspond to Nash profits. Indicating by \( \delta \) the discount factor common to each firm \((0 < \delta < 1)\), remaining in the
The cartel will be individually profitable if:

$$\sum_{t=0}^{\infty} \delta^t \pi^c \geq \pi^d + \sum_{t=1}^{\infty} \delta^t \pi^N$$

(1.1)

The LHS of this inequality provides the discounted sum of collusive profits in all periods, whereas the RHS corresponds to the sum of total profits during the defection period and duopoly profits thereafter. The above inequality can be rearranged to give the following participation condition for the collusive agreement:

$$\delta > \delta^g = \frac{\pi^d - \pi^e}{\pi^d - \pi^N}$$

(1.2)

In (1.2), we have introduced $\delta^g$ as the critical discount factor, common to both firms, denoting the threshold of $\delta$ such that each firm is just indifferent between staying in the implicit cartel and defecting. Since the scope for collusion is measured by the range of values of $\delta$ above $\delta^g$, the cartel will be more stable, the lower the critical discount factor.

**Optimal punishments.** Abreu (1986; 1988), Abreu, Pierce and Stacchetti (1986) and Fudenberg and Maskin (1986) pioneered the concept of stick-and-carrot punishments in repeated games. They showed that, when players adopt optimal two-phase punishments instead of reverting to the one-shot Nash equilibrium strategy (Friedman, 1971), the scope for collusive agreements is maximized.

Following Abreu (1986; 1988), if a deviation occurs at time $t$, both players adopt the punishment strategy symmetrically at time $t + 1$, and then they revert to the initial collusive path from time $t + 2$ onwards. If otherwise at time $t + 1$ one of the two players does not conform to the prescribed penal code, the punishment phase continues until both players take the same action in the penal period. Abreu (1986) shows that if there exist a quantity and a discount

---

2The discount factor is the same for both firms since both firms compute their discount factor by using a common market interest rate. Moreover, as usual in the repeated games literature, the discount factors are common knowledge and constant over time.
factor such that the following system of equations is satisfied:

\[
\begin{align*}
\pi^d - \pi^c &= \delta^o \left[ \pi^c - \pi^{opp} \right] \\
\pi^{dop} - \pi^{opp} &= \delta^o \left[ \pi^c - \pi^{opp} \right]
\end{align*}
\] (1.3)

then there exists no punishment rule which can sustain full collusion when \( \delta < \delta^o \). In (1.3), \( \pi^{opp} \) denotes each firm's stage profit when both firms play the punishment strategy, whilst \( \pi^{dop} \) is the profit from a one-shot best response against the punishment strategy. The first equation of (1.3) provides the condition such that there are no private incentives to deviate from the collusive path, while the second equation of (1.3) provides the condition such that there are no private incentives to deviate from the prescribed penal code.

In order for firms to find it profitable to continue the supergame after any deviation from the initial collusive path, the following individual rationality constraint must be satisfied:

\[
\pi^{opp} + \sum_{t=1}^{\infty} \delta^t \pi^c \geq 0
\] (1.4)

If the above constraint were binding, each firm's discounted profit stream starting in a punishment period would be negative, implying that it would be preferable to stop production permanently.\(^3\)

1.3 Optimal punishments with detection lags

Implicit collusion can be difficult to sustain if players compete under a veil of ignorance concerning the actions of rivals. When players do not directly observe each other's decisions, punishments might be delayed.\(^4\) For instance, because of the secrecy of contracts, a deviation from a prescribed collusive agreement may be discovered by the player being cheated only with

\(^3\) When each firm is exactly indifferent between adhering to the prescribed penal code and suspending its production forever the s.c. security level is achieved (see Lambson 1987; 1994; 1995).

\(^4\) Fudenberg, Levine and Maskin (1994) established the first "folk theorem" for games in which players' decisions are not directly observable.
a lag. Also infrequent interaction among players may delay the punishment phase and therefore make deviation more attractive (see Tirole, 1988).

We consider an infinitely repeated two-player game with discounting. We assume that any unilateral deviation from a prescribed agreement is observed by the player being cheated only after \( n \) periods.\(^5\) Both players adhere to the following penal code (Abreu, 1986; 1988): if a deviation, occurred at time \( t \), is detected at the end of period \( t + n \), both players adopt the punishment strategy symmetrically at time \( t+n+1 \), and then, they revert to the initial collusive path from time \( t + n + 2 \) onwards. If, otherwise, at time \( t + n + 1 \) one of the two players does not conform to the prescribed penal code, the punishment phase continues until both players take the same action in the penal period.

The inequality below provides the condition such that there are no private incentives to deviate from the collusive path:

\[
\sum_{t=0}^{\infty} \delta^t \pi^c \geq \sum_{t=0}^{n} \delta^t \pi^d + \delta^{n+1} \pi^{op} + \sum_{t=n+2}^{\infty} \delta^t \pi^c \quad (1.5)
\]

The LHS of (1.5) corresponds to the discounted payoffs accruing to each player when the collusive strategy is played, while the RHS of (1.5) is the sum of three elements: \( \pi^d \) is the per period payoff that can be gained as a result of a deviation from the collusive path; \( \pi^{op} \) indicates the payoff associated with the symmetric punishment strategy, and last term denotes the collusive payoff that each player will get from the post-punishment period onwards.

The inequality below provides the condition such that there are no private incentives to deviate from the prescribed penal code:

\[
\pi^{op} + \sum_{t=1}^{\infty} \delta^t \pi^{c} \geq \sum_{t=0}^{n} \delta^t \pi^{dop} + \delta^{n+1} \pi^{op} + \sum_{t=n+2}^{\infty} \delta^t \pi^c \quad (1.6)
\]

where \( \pi^{dop} \) stands for optimal deviation from the punishment phase. The LHS of (1.6) is the

\(^5\) \( n \) could be hours, days, weeks, months, quarters, etc., depending on the specific case at stake.
payoff which can be obtained by adhering to the punishment strategy, while the RHS of (1.6) corresponds to the payoff accruing to each player deviating from the prescribed penal code.

By following Abreu (1986, 1988):

**Proposition 1** Let \((x^c, x^{op})\) be the optimal stick-and-carrot punishment with a \(n\) period detection lag. Then:

\[
\begin{align*}
\sum_{t=0}^{n} \delta^t \left[ \pi^d - \pi^c \right] &= \delta^{n+1} \left( \pi^c - \pi^{op} \right) \\
\sum_{t=0}^{n} \delta^t \left[ \pi^{dep} - \pi^{op} \right] &= \delta^{n+1} \left( \pi^c - \pi^{op} \right)
\end{align*}
\]

It is worth noting that when \(n = 0\) (no detection lags) we come back to Abreu's Theorem 15 (1986, p. 203).

As an illustration of Proposition 1, we determine optimal punishments under either simultaneous price (Bertrand) or quantity (Cournot) competition. For the sake of simplicity, we assume that \(n = 1\) and that market demand is given by \(p(X) = 1 - X\), where \(X\) denotes industry output. Production entails a constant marginal cost denoted by \(c > 0\). In case of price competition, by using Proposition 1, and by taking into account that \(\pi^{dep} = 0\) and that \(\pi^d = 2\pi^c\), we get the following critical discount factor: \(\delta^*_B = 1/\sqrt{2}\). Since without any detection lags the critical discount factor associated with optimal penal codes under price competition amounts to 1/2, the presence of a delay in reacting to any deviation hinders cartel stability. It is easy to check that the incentive compatibility constraint (IRC), i.e. the condition ensuring that it is profitable for players to continue the supergame after any deviation, holds at the margin, implying that the s.c. security level is always achieved (see Lambson 1987).\(^6\)

Under quantity competition, the critical level of the discount factor such that collusion can be sustained as a subgame perfect equilibrium with one period detection lag turns out to be \(\delta^*_C = 0.4612\). Again, since the standard stick and carrot optimal punishments yield a critical discount factor equal to 9/32, the presence of a detection lag reduces the scope for collusion. It is easy to verify that the IRC is always satisfied.

\(^6\)Lambson (1994; 1995) relaxes the assumption of firms' *a priori* symmetry, showing that the security level may not be reached.
1.4 The suboptimality of optimal punishments in Cournot supergames

In this subsection we intend to investigate, within a Cournot supergame, whether optimal punishments may become suboptimal when the slope of the marginal cost is different from zero, namely, when economies of scale are not negligible. We compare the traditional grim trigger strategies (Friedman, 1971) with symmetric optimal penal codes in terms of critical discount factors sustaining full collusion. Our main results can be summarized as follows. First, we show that for sufficiently strong increasing returns to scale, the optimal punishment drives each firm down to the security level. Secondly, we show that for even stronger increasing returns to scale, the critical discount factor associated with grim trigger strategies is lower than the one associated with optimal penal codes.

Two a priori identical firms operate in the market over an infinite time horizon, selling perfect substitute products. The following assumptions are made:

A1: The discount factor $\delta \in (0,1)$ is constant over time and common to both firms.

A2: The marginal cost of production is linear: $c' = \alpha + \beta x_i > 0$, where $\alpha$ and $\beta$ are time-invariant parameters and $x_i$ is the quantity produced by firm $i = \{1,2\}$.

A3: At the beginning of every stage, firm $i = \{1,2\}$ produces and sells a quantity $x_i \in (0, \Psi (\delta)]$, where $\Psi (\delta)$ is such that $x_i > \Psi (\delta)$ would result in a violation of the individual rationality constraint to the continuation of the game.

A4: The (constant over time) inverse demand function is linear: $p = 1 - X$, where $X \in (0,1)$ denotes total industry output.

In A2, notice that $\beta$ is the returns to scale parameter: returns to scale are increasing.

7The results derived in this part of the chapter do not change qualitatively if we consider more than two firms and/or imperfect substitutes.
We consider full cartelization, i.e. during the collusive phase, the cartel acts as a unique firm aimed at maximizing the industry profit. This, along with the assumption that the cartel profit is symmetrically split, implies that the per firm collusive quantity and profit are:

\[ x^c = \frac{1 - \alpha}{\beta + 4}; \quad \pi^c = \frac{(1 - \alpha)^2}{2(\beta + 4)} \]  

The optimal deviation from the collusive agreement can be easily computed as follows:

\[ \max_{x^d} \left\{ \left(1 - x^d - x^c - \alpha \right) x^d - \beta \left(\frac{x^d}{2}\right)^2 \right\} \]  

where \( x^d \) stands for deviation quantity. The solution is given by:

\[ x^d = \frac{(1 - \alpha)(3 + \beta)}{(2 + \beta)(4 + \beta)} \]  

and the resulting deviation profit turns out to be:

\[ \pi^d = \frac{(1 - \alpha)^2(3 + \beta)^2}{2(2 + \beta)(4 + \beta)^2} \]  

As to the punishment phase, firms follow either trigger strategies or optimal penal codes.

Following Friedman (1971), collusion can be sustained as a subgame perfect equilibrium of the infinitely repeated game if \( \delta \) is larger than a critical threshold given by \( \delta^* = (\pi^d - \pi^c)/(\pi^d - \pi^N) \). Routine computations lead to the following one shot Nash equilibrium quantity and profit:

\[ x^N = \frac{1 - \alpha}{3 + \beta}; \quad \pi^N = \frac{(1 - \alpha)^2(\beta + 2)}{2(3 + \beta)^2} \]  

\(^{a}\)Abreu (1986, p. 195) assumes that the unit production cost is constant and equal to \( \alpha \).

\(^{b}\)Second order conditions are satisfied \( \forall \beta > -2 \). Furthermore, \( \alpha < 1 \) for quantities to be admissible.
By plugging the relevant expressions into the definition of $\delta^g$ we obtain:

$$
\delta^g = \frac{(3 + \beta)^2}{2(\beta + 2)^2 + 4\beta + 9}
$$

(1.12)

Now we proceed to determine the critical discount factor and the symmetric optimal punishment. During a punishment period, the profit accruing to each firm can be simply computed by imposing $x_t = x^{op}$ into the definition of profits. In order to compute the optimal deviation from the punishment phase, the cheating firm has to maximize its own profit taking into account that its rival sticks to the punishment strategy $x^{op}$. The optimal deviation from the prescribed penal code amounts to:

$$
z^{dop} = \frac{(1 - \alpha - x^{op})^2}{2(2 + \beta)}
$$

(1.13)

By plugging the relevant expressions into the system (1.3) and by solving for $\delta^o$ and $x^{op}$ we get:

$$
x^{op} = \frac{(1 - \alpha)(5 + \beta)}{(3 + \beta)(4 + \beta)}
$$

(1.14)

$$
\delta^o = \frac{(3 + \beta)^2}{4(2 + \beta)(4 + \beta)}
$$

(1.15)

Now, we check whether the IRC is satisfied. By using (1.14), (1.15) and (1.7), after rearranging, (1.4) becomes:

$$
\frac{(84\beta + 50\beta^2 + 12\beta^3 + \beta^4 + 49)}{(23 + 18\beta + 3\beta^2)} \geq 0
$$

(1.16)
The picture of the left hand side of (1.16) is provided below.

By looking at Fig. 1.1, if \( \beta < -1.8453 \) then the IRC is binding and firms will find it preferable to abandon production permanently. Furthermore:

**Lemma 1** If \( \beta = -1.5858 \), then the optimal punishment drives each firm down to the security level.

As we move from \( \beta = -1.5858 \) leftward, each firm's discounted profit stream starting in a punishment period increases exponentially, implying that the punishment becomes less and less severe. In the right neighborhood of the vertical asymptote, the effectiveness of the punishment tends to zero, as well as for the scope of collusion. Therefore, since the punishment profit under Nash-Cournot reversion tends to zero only when \( \beta \) tends to \(-2\), if \( \beta \in (-1.8453, -1.5858) \) then there must exist a region such that Nash-Cournot reversion is a stronger punishment than Abreu's.
By comparing (1.12) with (1.15) we can state:

**Proposition 2** If $\beta \in (-1.8453, -1.7753)$ then $\delta^g < \delta^o$, i.e. the optimal punishment is no longer optimal.

![Graph](image)

*Fig. 1.2: $\delta^g$ vs $\delta^o$*

### 1.5 Concluding Remarks

In this chapter we have shown how the presence of a $n$ period detection lag affects the derivation of optimal penal codes. The possible applications of our result abound. In the two simple examples provided, we have pointed out that, when deviation payoffs can be gained for an additional period, cartel stability is reduced. Within a Cournot supergame, we have also shown that, when production exhibits strong increasing returns to scale, Abreu's optimal punishments fail to be optimal, in the sense that there exists another penal code, Nash reversion, such that the associated critical discount factor is lower, that is the scope for collusion is higher.
Chapter 2

Sustaining Collusion under Economic Integration

2.1 Introduction

According to the World Trade Organization (WTO) and the World Bank Group, a growing proportion of cartel agreements are international in scope. A good indicator of such an international dimension of cartels is the overwhelming number of collusive agreements involving international firms prosecuted by the US Department of Justice in the 1990s.

To be considered international, a cartel must involve more than one producer; include firms from more than one country; have attempted to set prices or divide markets in more than one country. The industry evidence on the 1990s international cartels suggests that they operated in a variety of industries, including chemicals, metals, paper products, transportation, and services. Moreover, it seems that they were formed as a result of increasing competition and market integration (see Evenett et al., 2001).

In this chapter, we aim at investigating from a game theory perspective whether trade

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1 This chapter is based on a joint work with Luca Colombo (2006c).
liberalization can promote a collusive two-way trade. Under the assumptions of a constant returns to scale production function and homogeneous good, the existing literature studying the effects of trade liberalization on the stability of international cartels assumes that collusion is enforced by the understanding to sell only into the domestic market. Pinto (1986), in a repeated game version of the Brander and Krugman's model (1983), shows that such an understanding is optimal for firms in terms of joint profit maximization, i.e. it represents an efficient outcome neither firm can improve upon acting unilaterally. As a consequence, if international trade is observed, firms are not sustaining any collusive agreements. Fung (1991; 1992), first shows that a theoretical possibility for implicit collusion to be associated with international trade exists when products are differentiated.3

In this chapter, we provide a model of two-way trade that allows implicit collusion to arise as a possible outcome of the repeated game even when international trade takes place, keeping the assumption of homogeneous good. Indeed, if the assumption of differentiated goods is surely appropriate for many industries, in many others where collusive trade has been documented, homogeneity in goods seems a better description of reality. For instance, the food additive cartel, the vitamin cartel, the graphite electrodes cartel, the lysine cartel and the plasterboard cartel, to mention a few, all active in the 1990s and prosecuted by the US Justice Department or the European Commission, are cartels made up by international firms selling almost completely standardized products.4

An additional possible drawback of the existing literature dealing with trade liberalization and collusion is that it focuses on constant returns to scale production functions, exclusively. Yet, economies of scale are non negligible in many industries where firms seem to behave cooperatively, either by setting prices or quantities.5 An increasing/decreasing marginal cost

3In a setting with differentiated products, Colonescu and Schmitt (2003) address the issue of collusive sustainability with multimarket contact. On collusion with multimarket contact see also Bernheim and Whinston (1990).

4In general, it seems that products exchanged across E.U. borders are sufficiently similar to make Fung's arguments empirically irrelevant to european integration (see Smith and Venables, 1988).

5The analysis of scale economies in models of international trade with imperfect competition can be found
of production would make the analysis interesting, the reason being that, unlike in a constant unit cost case, the level of trade costs would affect not only marginal revenues but also marginal costs. As a consequence, in a setting with non linear production costs, the stability of implicit collusion would depend not only on market competition, but also on technology.

Our main goal is to provide a theoretical appraisal of the possibility that trade liberalization may increase the scope for collusive trade, assuming away constant returns to scale as well as product differentiation. Throughout the chapter, we stick to the so called hard core cartels, made up of private producers from at least two countries who cooperate to control prices or allocate shares in world markets. As usual in the literature, we consider trade liberalization as a reduction in per unit trade costs, namely, transport costs, specific tariffs (particularly relevant on agricultural products), ad valorem tariffs on intermediate goods (see Mujumdar, 2004), regardless of whether the cuts are large or small.

Looking at the existing related literature dealing with intra-industry trade, whether economic integration is pro-competitive depends on several factors, among which the type of market competition, price or quantity, the nature of products, imperfect or perfect substitutes, the prescribed penal codes, trigger strategies or optimal punishments and the definition of trade costs. To our knowledge, how scale economies affect the relationship between trade costs and the stability of international collusion is an open issue.

The work closer to ours is probably Lommerud and Sørgard (2001), LS henceforth. They consider both price and quantity competition in an infinitely repeated duopoly game with perfect substitutes and constant returns to scale production function showing that, under quantity competition, a reduction in per unit trade costs is always pro-competitive, while under price

in Krugman (1979), Ethier and Horn (1984), Helpman and Krugman (1985), Smith and Venables (1988) and Krugman (1991), inter alia. However, the possibility that firms behave cooperatively is not considered.

Hard core cartels differ from export cartels, where private or state run firms from one country agree to fix prices or market shares in export markets, but not in their domestic market.

In our partial equilibrium setting we have a unique trade cost, $\tau$. For a general equilibrium analysis of trade liberalization in the presence of tariffs and quotas see Anderson and Neary (1992) and Neary (2006).

Davidson (1984), Rotemberg and Saloner (1989) and Fung (1992) address the issue whether trade liberalization enhances cartel stability, assuming that firms compete only in one country. Two-way trade, either collusive or not, is not considered.
competition, the opposite holds true. The main difference with respect to our analysis is that they assume that for each firm collusion consists in selling only into the domestic market. In their setting, this corresponds to the solution of joint profit maximization, i.e. it constitutes a strong Nash equilibrium of the repeated game. However, we show that it may become optimal for firms to start a two-way trade during the collusive phase, as the production function exhibits sufficiently decreasing returns to scale. In contrast to LS, we find that the collusive profits may depend on the level of trade costs and that the occurrence of collusive trade is crucially responsible for a new set of results. We prove that, under quantity competition, economic integration is anti-competitive if collusive trade may arise as a possible outcome of the repeated game. Under price competition, the likelihood of collusive trade is a necessary but not sufficient condition for trade liberalization to be pro-competitive. Furthermore, we show that there exists an economically meaningful parameter region where economic integration enhances cartel stability no matter firms' strategic variable. LS show that under constant returns to scale a price game leads to a different outcome concerning collusion than a quantity game.

By relaxing the assumption of constant unit cost, our analysis shows that the same outcome (collusion-enhancing trade liberalization) can be obtained, implying that production technology has a strong influence on the outcome, not the game only. Given that the cost function we use includes also the constant unit cost case, our study could be interpreted as a generalization of LS. When scale economies come into the picture, the results we are accustomed to from LS, which are related to those derived by Pinto (1986), may be overturned. This should not be too surprising, since the incentives to collude are directly linked to the incentives of restricting outputs, which depend also on the shape of the cost function. As a consequence, it seems not plausible to get rid of scale economies in analyzing the incentives for firms to take part in international cartels, as well as in signing the relationship between trade liberalization, i.e. reduction in trade costs, and the stability of international cartels.

The authors adopt also Abreu's (1986) optimal punishments, showing that the conclusion on price competition is reversed.
The remainder of this chapter is structured as follows. The model and the analysis are provided in Section 2.2. Concluding remarks are in Section 2.3.

2.2 The Model

Two firms, firm $a$ located in country $A$ and firm $b$ located in country $B$, are engaged in quantity (Cournot) or price (Bertrand) competition over an infinite time horizon. Let $q_i$ and $q_i^*$ denote the output that firm $i = \{a, b\}$ produces for domestic and foreign consumption, respectively. In each country, the inverse demand function is given by:

$$ p_j = 1 - Q_j, \quad j = \{A, B\} $$

where $Q_A = q_a + q_a^*$ and $Q_B = q_b + q_b^*$ stand for industry output in country $A$ and $B$, respectively.

On the supply side, we relax the usual assumption of constant returns to scale, by considering the following production cost function:

$$ c_i (q_i, q_i^*) = \alpha (q_i + q_i^*) + \frac{\beta}{2} \left( q_i^2 + (q_i^*)^2 \right), \quad i = \{a, b\} $$

which can accommodate decreasing, constant or increasing returns to scale, depending on the value assumed by the scale economies parameter, $\beta$. If $\beta > (\leq) 0$ returns are decreasing (increasing), while they are constant if $\beta = 0$. The assumed cost function means essentially that the firm has two plants or one plant with two production lines, one for domestic sales and the other for exports: returns to scale are at the plant level. The advantage of working with (2.2) is that, as in a constant unit cost case, where the number of plants is irrelevant, the firm’s quantity decisions at home and abroad are completely separate decisions. This is consistent with the usual assumption (also in LS) that the choice on how much to produce for foreign consumption does not depend on the choice on how much to produce for domestic consumption. The key feature of (2.2) is that the production process required to produce a
unit for the foreign market, to some extent, even marginal, differs from the one required to produce a unit for the domestic market. For instance, a car to be sold in UK, compared to a car to be sold in Continental Europe, differs in the placement of the steering-wheel, therefore the production process, at a certain point, must differ.\textsuperscript{10} The presence of $\beta \neq 0$ allows us to capture the effects of trade costs not only on marginal revenues but also on marginal costs. This implies that, unlike in the constant returns to scale case, the stability of implicit collusion will depend not only on market competition, but also on technology. For the sake of simplicity, without any loss of generality (since cartel stability is not affected) let us normalize $a$ to zero. Trade is associated with per unit trade costs $\tau$ incurred in exporting goods from one country to the other, with $0 < \tau < 1/2$ for collusion being always profitable. Under price competition, if $\tau \geq 1/2$ then the level of trade costs is prohibitive irrespective of the firms’ behavior, meaning that no room is left for collusive agreements. Trade costs can be thought of as transportation costs and/or specific tariffs, for instance tariffs levied on intermediate goods (see Mujumdar 2004). As usual in the literature, we interpret economic integration as a reduction in these trade costs.

We model firms interaction in the market as a repeated price or quantity game over an infinite time horizon. Following Friedman (1971) and Fudenberg and Maskin (1986), each firm sticks to the cooperative strategy as long as the rival does likewise.\textsuperscript{11} If a deviation is detected, say at time $t$, both firms revert to the one shot Nash equilibrium strategy from time $t + 1$ onwards. Collusion can be sustained as a subgame perfect equilibrium of the infinitely repeated game if the discount factor $\delta \in [0, 1)$, common to both firms, is larger than a critical threshold given by $\delta_K = (\pi_d^K - \pi_c^K) / (\pi_d^K - \pi_N^K)$, where superscripts $d$, $c$ and $N$ stand for deviation, collusion and Nash respectively, while the subscript $K = \{P,Q\}$ denotes the kind of market

\textsuperscript{10}As pointed out by an anonymous referee, an alternative to (2.2) could have been $c_i(Q) = \alpha q + \beta/p$, with $Q = q_i + q_i'$. However, the domestic and the foreign markets would have been no longer independent since the same plant would have been used for both $q_i$ and $q_i'$.

\textsuperscript{11}There exist more severe punishments than Nash reversion, dating back to Abreu (1986), the s.c. optimal punishments. Optimality comes from the fact that if firms adhere to them, then the scope for collusion is maximized. However, throughout our analysis, the use of optimal punishments is not allowed given that the unit cost of production is not constant (see Abreu 1986, p. 195).
competition, price or quantity.

Throughout the chapter, we consider full cartelization, i.e. during the collusive phase, the cartel acts as a unique firm aimed at maximizing the sum of the profits that each individual firm obtains from selling at home and abroad. Under the assumption of constant returns to scale, the joint profit maximization yields a solution without trade. However, collusion can be sustained not necessarily staying at home. Indeed, collusion can be associated with trade whenever the maximization of joint profit yields inner solutions, meaning that each firm produces a strictly positive quantity for the foreign market. In formal terms, the cartel's maximization problem writes:

\[
\max_{\pi_a, \pi_b} \left\{ \pi_a + \pi_b \right\} \quad \text{s.t. } q_i \geq 0, \quad q_i^* > 0, \quad i = \{a, b\}
\]

where \( \pi_a = p_A q_a + (p_B - \tau) q_a^* - c_a \) and \( \pi_b = p_B q_b + (p_A - \tau) q_b^* - c_b \). Whenever inner solutions to \( \mathcal{P} \) exist, firm \( i \)'s collusive quantity, \( i = \{a, b\} \), and the price level in each country are given by:

\[
q_i^c = \frac{\beta + 2\tau}{\beta(4 + \beta)}; \quad q_i^{*c} = \frac{\beta - (\beta + 2) \tau}{\beta(4 + \beta)}; \quad p^f = \frac{2 + \beta + \tau}{4 + \beta}
\]

with \( \beta > \bar{\beta} = 2\tau / (1 - \tau) \) for \( q_i^{*c} > 0 \), i.e. for collusive trade to exist. Otherwise, firms sustain a collusive agreement consisting in not exporting into each other domestic market, i.e. \( q_i^{*c} = 0 \).

When no trade takes place in the collusive phase, each firm acts as a monopolist at home selling \( q_i^e = 1 / (2 + \beta) \) at a price \( p^e = (1 + \beta) / (2 + \beta) \).

**Proposition 3** If returns to scale are sufficiently decreasing, i.e. \( \beta > \bar{\beta} \), collusive trade may arise. Otherwise, collusive trade does not exist.

Notice that since \( \bar{\beta} > 0 \), when increasing returns to scale prevail it is never profitable for a colluding firm to start exporting. The intuition is that the restriction in output necessary to sustain a collusive agreement in both markets is too costly given the shape of the cost function.

\[\text{\textsuperscript{12}}\text{Throughout the chapter, second order conditions are always satisfied. They are omitted for brevity.}\]
Each firm prefers to enjoy monopoly profits no matter the level of trade costs. In the opposite case, decreasing returns favor collusion since it is a form of commitment for firms to reduce output while deviation from the collusive path, by requiring output expansion, is costly. It is also worth noting that $\beta > \hat{\beta}$ is a necessary but not sufficient condition for collusive trade to actually arise. Indeed, a collusive trade will be sustained in equilibrium if $\beta > \hat{\beta}$ and $\delta > \delta_K$.

The individual collusive profits amount to:

$$\pi_i^c = \begin{cases} 
\frac{2\tau^2 + \beta [2 + (\tau - 2) \tau]}{2\beta (4 + \beta)}, & \text{with collusive trade} \\
\frac{1}{2 (2 + \beta)}, & \text{without collusive trade}
\end{cases} \quad (2.4)$$

Notice that $\tau$ enters into the expression of $\pi_i^c$ only when collusive trade occurs. Since $\partial \pi_i^c / \partial \tau < 0$, a reduction in trade costs, ceteris paribus, makes collusion more profitable. Such an anti-competitive effect does not come out with constant returns to scale.

### 2.2.1 Quantity Setting

We examine the case of quantity competition. Suppose one firm decides to break down the international cartel. The one period deviation quantity has to be computed given that the rival's production corresponds to the individual collusive level. We have to distinguish between two scenarios, depending on whether collusive trade exists.

Consider first $\beta > \hat{\beta}$, which is the case in which colluding firms are selling both at home and abroad. The cheating firm's objective function:

$$\pi_i = (1 - q_i^d - q_i^{de}) q_i^d - \frac{\beta (q_i^d)^2}{2} + (1 - q_i^{de} - q_i^e - \tau) q_i^{de} - \frac{\beta (q_i^{de})^2}{2} \quad (2.5)$$

which can be maximized with respect to $q_i^d$ and $q_i^{de}$. Solutions are given by:

$$q_i^d = \frac{2 \tau + \beta (3 + \beta + \tau)}{\beta (2 + \beta) (4 + \beta)}; \quad q_i^{de} = \frac{\beta (3 + \beta) - [2 + \beta (4 + \beta)] \tau}{\beta (2 + \beta) (4 + \beta)} \quad (2.6)$$
Notice that $q_i^d > q_i^{rd}$ in the entire parameter range. The domestic deviation quantity is always higher than the deviation quantity abroad. By plugging (2.6) into (2.5), the overall deviation profit obtains:

$$\pi_i^d = \frac{2\beta^2 (3 + \beta)^2 (1 - \tau) + (8 + \beta (4 + \beta) [5 + \beta (4 + \beta)]) \tau^2}{2\beta^2 (2 + \beta) (4 + \beta)^2}$$  \hspace{1cm} (2.7)$$

Now, consider $\beta \le \tilde{\beta}$. The collusive agreement consists in selling only into each domestic market, and no collusive trade takes place. Since the monopoly profit at home is guaranteed, deviation has to be computed by looking at the foreign market only. The cheating firm has to set the export quantity, $q_i^{rd}$, given that the rival continues to play the collusive strategy. The cheating firm's objective function can be thought of as:

$$\pi_i = \frac{1}{2 (2 + \beta)} + \left(1 - q_i^{rd} - \frac{1}{2 + \beta} - \tau\right) q_i^{rd} - \frac{\beta (q_i^{rd})^2}{2}$$ \hspace{1cm} (2.8)$$

which can be maximized with respect to $q_i^{rd}$. The solution turns out to be:

$$q_i^{rd} = \frac{1 + \beta - 2\tau - \tau\beta}{(2 + \beta)^2}$$ \hspace{1cm} (2.9)$$

Accordingly, the overall deviation profit is:

$$\pi_i^d = \frac{2\beta^2 - 2\beta^2 \tau + \tau^2 \beta^2 + 6\beta - 6\tau \beta + 4\tau^2 \beta + 4\tau^2 - 4\tau + 5}{2 (2 + \beta)^3}$$ \hspace{1cm} (2.10)$$

Once a deviation is detected, each firm moves back to the Cournot-Nash equilibrium. Routine computations lead to the following equilibrium quantities:

$$q_i^N = \frac{1 + \beta + \tau}{(3 + \beta) (1 + \beta)}; \quad q_i^{N*} = \frac{1 + \beta - (2 + \beta) \tau}{(3 + \beta) (1 + \beta)}$$ \hspace{1cm} (2.11)$$

with $\beta > (2\tau - 1) / (1 - \tau)$ for $q_i^{N*} > 0$. However, since $\tilde{\beta} > (2\tau - 1) / (1 - \tau)$, if collusive trade
exists then \( q^N_i > 0 \) always. The one shot Nash equilibrium profit amounts to:

\[
\pi^N_i = \frac{(2 + \beta) \left[ 2(1 + \beta)^2 (1 - \tau) + [5 + \beta (4 + \beta)] \tau^2 \right]}{2 (3 + \beta)^2 (1 + \beta)^2}
\]  

(2.12)

By using all the relevant profits expressions, we are in a position to compute the critical discount factor, \( \delta_Q \). It is well known that collusion can be sustained as a subgame perfect equilibrium of the infinitely repeated game if and only if the discount factor \( \delta \in [0, 1] \), which, given the symmetry assumption, is common to both firms, is larger than \( \delta_Q \) (the expression for \( \delta_Q \) is provided in the Appendix).

Now, let us check how a change in per unit trade costs \( \tau \) affects the critical discount factor:

\[
\frac{\partial \delta_Q}{\partial \tau} \leq 0, \ \forall \beta \leq \beta
\]

\[
\frac{\partial \delta_Q}{\partial \tau} > 0, \ \forall \beta > \beta
\]

Proposition 4 In the quantity setting, if the likelihood of collusive trade exists, any economic integration increases the scope for international collusion. Otherwise, the opposite holds true.

2.2.2 Price Setting

We assume competition takes place in prices. The optimal deviation consists in setting the price level equal to \( p^f - \varepsilon \), with \( \varepsilon \to 0 \). In doing so, the cheating firm earns the monopoly profits both at home and abroad. As before, we have to distinguish between two scenarios, depending on whether collusive trade exists:

\[
\pi^d_i = \begin{cases} 
\frac{2 (2 - \tau)^2 (4 + \beta)^2}{(4 + \beta)^2}, & \forall \beta > \beta \\
\frac{1 - \tau}{\beta + 2}, & \forall \beta \leq \beta
\end{cases}
\]

(2.13)

During the punishment phase, each firm reverts to the one shot Nash equilibrium strategy.
The stage game is a Bertrand game with asymmetric costs, since the cost of selling abroad is augmented by \( \tau \). As a consequence, as in the constant returns to scale case, no trade arises after a deviation has been detected, implying that each firm earns a positive profit only by serving the domestic market. The equilibrium price level can be computed by setting the rival's profits from exports equal to zero, that is \((p - \tau)(1 - p) - \beta/2 (1 - p)^2 = 0\). The admissible solution is:\(^{13}\)

\[
p^N = \frac{\beta + 2\tau}{2 + \beta}
\]

which is admissible as long as \( \tau < 1/2 \). If \( \tau \) were higher than 1/2, the Bertrand-Nash and the collusive profits would coincide, meaning that the critical discount factor would approach 1, leaving no room for any collusive agreements. The resulting Bertrand-Nash profits are:

\[
\pi^N_i = \frac{2\tau (1 - \tau)}{2 + \beta}
\]

By using all the relevant profits expressions, we compute \( \delta_p \), the lowest discount factor for which collusion is sustainable (the expression of \( \delta_p \) is provided in the Appendix). A change in per unit trade costs \( \tau \) affects \( \delta_p \) as follows:

\[
\frac{\partial \delta_p}{\partial \tau} \propto \Omega, \quad \forall \beta > \bar{\beta}
\]

\[
\frac{\partial \delta_p}{\partial \tau} \geq 0, \quad \forall \beta \leq \bar{\beta}
\]

where \( \Omega = \{4 (3\tau - 2) [\tau - \beta (1 - \tau)] - \beta^2 [2 - \tau (4 - \tau)]\} \), which is negative if:\(^{14}\)

\[
\beta > \tilde{\beta} = 2 \frac{3\tau^2 - 5\tau + 2 + (1 - 2\tau) \sqrt{3\tau^2 - 8\tau + 4}}{2 - 4\tau + \tau^2}
\]

---

\(^{13}\)To avoid multiplicity of equilibria (see Dastidar, 1995), we consider \( \beta < 4 \).

\(^{14}\)The other root is not relevant to the analysis, since it belongs to the region in which no collusive trade arises. Formally, \( \tilde{\beta} > 2 \frac{3\tau^2 - 5\tau + 2 + (1 - 2\tau) \sqrt{3\tau^2 - 8\tau + 4}}{2 - 4\tau + \tau^2} \).
Proposition 5 In the price settings, if there are sufficiently decreasing returns to scale, i.e. \(eta > \bar{\beta}\), any economic integration reduces the scope for international collusion. Otherwise, the opposite holds true.

While in the Cournot setting, by Proposition 4, trade liberalization is anti-competitive if and only if colluding firms find it profitable to engage in two-way trade, in the Bertrand setting, the occurrence of collusive trade per se is not sufficient to sign the derivative of the critical discount factor w.r.t. the level of trade costs. A reduction in trade costs yields two collusion-reducing effects (a decrease in the levels of deviation and collusive profits) and one collusion-enhancing effect (an increase in punishment profits), the magnitudes of which are captured by \(\beta\). When \(\beta\) is relatively low, in particular it is lower than \(\bar{\beta}\), provided that the derivative of punishment profits w.r.t. \(\beta\) is negative, the collusion-enhancing effect prevails. The intuition is that it becomes non-profitable to deviate from the collusive agreement because it is not too costly to punish the cheating firm. On the contrary, when \(\beta\) is relatively high, i.e. \(\beta > \bar{\beta}\), Nash profits become so small that the two collusion-reducing effects prevail. Collusion tends to fail because it becomes very expensive to punish the cheating firm.

2.2.3 Price vs Quantity

From a comparison between price and quantity competition, we can directly state:

Proposition 6 If \(\beta \in (\bar{\beta}, \bar{\beta})\), irrespectively of whether competition takes place in prices or quantities, any economic integration increases the scope for international collusion.

The following figure summarizes all the relevant results.
It is worth noting that without collusive trade (Area I), economic integration turns out to be pro-competitive under quantity competition and anti-competitive under price competition. When the possibility of collusive trade is taken into account, which in our model is equivalent to considering sufficiently decreasing returns to scale (Area II), a reduction in trade costs is anti-competitive both under price and quantity competition. Quite interestingly, as soon as the economies of scale parameter reaches a certain threshold, given by \( \bar{\beta} \) (Area III), economic integration is pro-competitive under price competition and anti-competitive under quantity competition, exactly the opposite result we get in the absence of collusive trade. Moreover, by looking at Figure 2.1, we notice that, under quantity competition, for any given \( \beta \in (0, 2) \), there exists a non monotone relationship between \( \hat{\delta}_Q \) and \( \tau \); under price competition, for any given \( \beta \in (2, 4) \), there exists a non monotone relationship between \( \hat{\delta}_P \) and \( \tau \).
In case of a non monotone relationship between the critical discount factor and the level of trade costs, the derivative of $\delta_K$ with respect to $\tau$ is first increasing and then decreasing, with $K = \{P, Q\}$. Therefore, a level of trade costs exists such that the scope for collusion is minimized.

By inverting $\lambda$ and $\tilde{\lambda}$ for quantity and price competition respectively, the collusion minimizing levels of $\tau$ in the two settings are:

$$
\tau^C_{Q} = \frac{\beta}{2 + \beta}, \quad \tau^C_{P} = \frac{2\beta (\beta - 4)}{2[(\beta - 5) \beta - 2] - \sqrt{2}(\beta - 2) \sqrt{2 + \beta^2}}
$$

(2.17)

where superscript $CM$ stands for collusion minimizing.

**Proposition 7** Under quantity competition, if $\tau = \tau^C_{Q}$ then the scope for collusion is minimized; under price competition, if $\tau = \tau^C_{P}$ then the scope for collusion is minimized.

From a policy perspective, if the economy is on any point such that $\tau > \tau^C_{K}$, with $K = \{P, Q\}$, for a given level of $\beta$, any reduction in trade costs makes collusion less sustainable. But, if the economy starts from any point such that $\tau < \tau^C_{K}$, with $K = \{P, Q\}$, further reduction in trade costs will increase the likelihood of international collusive agreements. As a consequence, as far as cartel stability is concerned, it should be preferable to increase rather than decrease $\tau$ until $\tau^C_{K}$ is reached.

### 2.3 Concluding Remarks

In this chapter, we have investigated from a game theory perspective whether reduced trade barriers can promote a collusive two-way trade. Under the assumptions of a constant returns to scale production function and homogeneous good, the existing literature investigating the effects of trade liberalization on the stability of international cartels assumes that collusion is enforced by the understanding to sell only into the domestic market. To our knowledge, homogeneity in good has never been associated with collusive two-way trade. By relaxing the assumption of
constant returns to scale, our analysis has unveiled that implicit collusion among international firms can take the form of collusive two-way trade, depending on the nature of production costs. We have shown that a necessary condition for collusive trade to arise is that returns to scale are sufficiently decreasing. Otherwise collusive trade does not exist. In the quantity setting, if collusive trade exists, any economic integration increases the scope of collusive agreements. Otherwise, the opposite holds true. This is in contrast with the conventional wisdom according to which, if quantity competition prevails, then a reduction in trade barriers is always pro-competitive. We have shown that even the slightest presence of diseconomies of scale yields a non monotone relationship between the critical discount factor and the level of trade costs. Under price competition, if the production technology exhibits sufficiently decreasing returns to scale, any economic integration reduces the scope for collusion. Otherwise, the opposite holds true. From a comparison between the two settings, we have found a parameter region where any economic integration enhances cartel stability irrespectively of whether competition takes place in prices or quantities.

From a policy perspective, it is well know that open up to trade is always socially desirable compared to autarchy (even if collusive trade arises). However, without intending to question the overall beneficial effectiveness of two-way trade, our analysis has suggested that a reduction in trade costs could bring along collusion whereas collusion was not previously sustainable. Therefore, economic integration does not seem to automatically provide the necessary competitive discipline, implying that competition policy should be even more vigilant as markets become more integrated, particularly when trade liberalization is under completion, i.e. when \( \tau \) is relatively low. All the possible beneficial effects of trade liberalization may be offset by the negative effects ascribed to international collusion.
2.4 Appendix

Critical discount factor in case of quantity competition:

$$\tilde{\delta}_Q = \frac{(1 + \beta)^2 (3 + \beta)^2 (8\tau + 4\beta\tau^2 + \beta^2 (2 + (-2 + \tau) \tau))}{2\beta^2 (1 + \beta)^2 (17 + 2\beta (6 + \beta)) (1 - \tau) + \Omega \tau^2}, \quad \forall \beta > \bar{\beta} \quad (2.18)$$

where $$\Omega = (72 + \beta (4 + \beta) (93 + \beta (4 + \beta) (27 + 2\beta (4 + \beta))))$$

$$\tilde{\delta}_Q = \frac{(1 + \beta - 2\tau - \tau\beta) (3 + \beta)^2 (1 + \beta^2)}{2\beta^4 + 3\tau\beta^3 + 13\beta^3 + 18\beta^2 \tau + 31\beta^2 + 35\beta\tau + 33\beta + 22\tau + 13}, \quad \forall \beta \leq \bar{\beta} \quad (2.19)$$

Critical discount factor in case of price competition:

$$\hat{\delta}_P = \frac{(2 + \beta) \{2 (4 - \beta) \beta (1 - \tau) - [8 + \beta (2 + \beta)] \tau^2\}}{4\beta [3\tau - 2 - \beta (1 - \tau)] [(6 + \beta) \tau - 4]}, \quad \beta > \bar{\beta} \quad (2.20)$$

$$\hat{\delta}_P = \frac{1}{2 (1 - \tau)}, \quad \beta \leq \bar{\beta} \quad (2.21)$$

Uniqueness of Bertrand Nash Equilibrium:

We have a Bertrand game with asymmetric (non linear) costs, since the cost of selling abroad is augmented by $$\tau$$, the trade cost. The problem with the associated price equilibrium is that, although it always exists, it could be non-unique (see Dastidar, 1995). By following Dastidar (1995), we want to prove that the equilibrium price we used in the chapter, $$p^N = (\beta + 2\tau) / (2 + \beta)$$ is the unique admissible Bertrand-Nash equilibrium. As we are about to show it is always profitable for the domestic firm to set a price that keeps the foreign firm out of the domestic market (for any admissible $$\beta < 4$$, as shown in Figure 2.1). Therefore, all the three Areas in Figure 2.1 (Area I, II, III) are admissible. We are not interested in what happens for $$\beta > 4$$. Multiple equilibria exist only for $$\beta > 4$$.

A Nash equilibrium is such that for both players (the domestic firm and the exporting firm) there are no unilateral incentives to deviate from the equilibrium path.
By following Dastidar (1995), for the domestic firm, there are no incentives to deviate from a candidate equilibrium price if and only if:

\[
p \in \left[ \frac{\beta}{4 + \beta}, \frac{3\beta}{4 + 3\beta} \right]
\]  

(2.22)

Similarly, for the exporting firm, there are no incentives to deviate from a candidate equilibrium price if and only if:

\[
p \in \left[ \frac{4\tau + \beta}{4 + \beta}, \frac{3\beta + 4\tau}{4 + 3\beta} \right]
\]  

(2.23)

Therefore, if

\[
p \in \left[ \frac{4\tau + \beta}{4 + \beta}, \frac{3\beta}{4 + 3\beta} \right]
\]  

(2.24)

then, for both players, there are no unilateral incentives to choose a different price.

Hence, if the domestic firm decides to let the exporting firm enter its own domestic market and after the two firms, by adopting the same price, divide equally the market, then it could be the case that the Bertrand competition leads to multiple Nash equilibria. In this case, the maximum Nash profit the domestic firm can earn is (by using 2.24):

\[
\pi^{\text{MAX}} = \frac{4\beta}{(4 + 3\beta)^2}
\]  

(2.25)

However, it is worth noting that the domestic firm faces an alternative: instead of accommodating the entry of the exporting firm into its own domestic market, it can exploit its advantage and, as in our chapter, it can set the price such that its rival's profits from exports equal zero. In this case, the Bertrand Nash equilibrium price and profits write:

\[
p^N = \frac{\beta + 2\tau}{2 + \beta}; \pi_i^N = \frac{2\tau (1 - \tau)}{2 + \beta}
\]  

(2.26)

At this stage, we have to compare \(\pi^{\text{MAX}}\) and \(\pi_i^N\): if \(\pi_i^N > \pi^{\text{MAX}}\), the domestic firm will prefer for sure to get \(\pi_i^N\) and it will play \(p^N\) accordingly. Therefore, if \(\pi_i^N > \pi^{\text{MAX}}\) the price we
have computed in the chapter, $p^N = (\beta + 2\tau) / (2 + \beta)$ is the only admissible Nash Equilibrium price and it is unique. $\pi_i^N > \pi^{MAX}$ if:

$$\tau \in \left[ \frac{\beta}{4 + 3\beta} ; \frac{4 + 2\beta}{4 + 3\beta} \right] \quad (2.27)$$

Then, by comparing (2.24) and (2.27) turns out that :

$$\frac{4 + 2\beta}{4 + 3\beta} > \frac{3\beta}{4 + 3\beta} \implies \pi_i^N > \pi^{MAX} \quad (2.28)$$

Straightforward computations allow us to claim that: $\pi_i^N > \pi^{MAX} \forall \beta < 4$. This is the parameter range of $\beta$ we have considered in the chapter (notice that Figure 2.1 is closed right at $\beta = 4$). Indeed, whatever is the Nash Equilibrium associated with (2.24), the domestic firm gains always a lower profit by dividing its own domestic market with the exporting firm than by blocking completely the rival firm from exporting. $p^N = (\beta + 2\tau) / (2 + \beta)$ is the unique admissible Nash Equilibrium price.
Chapter 3

Commodity Taxation and Tariffs in Cournot Supergames

3.1 Introduction

Many factors affect the stability of implicit cartels: nature of market competition, nature of products, number of competitors, entry barriers, demand and supply characteristics. All these factors have been extensively analyzed in the literature, both theoretically and empirically.\footnote{For an exhaustive exposition see Ivaldi et al. (2003).}

The aim of this chapter is twofold: (i) to include commodity taxation in the analysis of implicit collusion; (ii) to provide new insights on the effects of tariffs on cartel stability.

In the first part of the chapter, we are interested in assessing how the two main forms of commodity taxation, namely ad valorem and specific, affect the sustainability of implicit collusive agreements. To this end, we compare ad valorem and specific taxation in terms of critical discount factors sustaining full collusion, within a standard closed economy two-firm model of quantity competition.\footnote{Delipalla and Keen (1992), Skeath and Trandel (1994), Myles (1996) and Anderson et al. (2001b), \textit{inter alia}, compare the welfare effects of ad valorem and per unit taxation in static oligopolistic frameworks, showing that, in general, ad valorem taxation is more efficient, in that it is associated with a lower deadweight loss. However, the possibility that firms take part in implicit cartels is not taken into account.} We first adopt the traditional grim trigger strategies...
dating back to Friedman (1971), then we assume that firms follow stick and carrots optimal punishments (Abreu, 1986, 1988; Abreu, Pierce and Stacchetti, 1986). We show that while specific taxation does not affect the stability of collusion, ad valorem taxation makes it easier or harsher for firms to collude depending on the nature of scale economies. As to the comparison, we show that, no matter the kind of punishment being used, if decreasing returns to scale prevail, then firms always find it easier to sustain a collusive agreement under ad valorem than under specific taxation. If, instead, technology exhibits increasing returns to scale, the opposite holds true. Therefore, in industries where collusion is likely and diseconomies of scale prevail, ad valorem taxation seems to be more collusion-enhancing than specific taxation, implying that specific taxation should be favored by an antitrust authority interested in fostering greater competition. It is worth noting that the focus of our analysis is on cartel stability. Since, in general, the objective of a fiscal authority differs from the objective of an antitrust authority as well as from the objective of a hypothetical social planner, the point we want to make is not which of the two taxes should be preferred on welfare grounds, rather, we want to shed some light on whether commodity taxation enhances implicit collusion and eventually under what circumstances. To our knowledge, with the exception of Haufler and Schjelderup (2004), dealing with tax rate harmonization and international cartels, this is the first attempt to consider commodity taxation, in particular ad valorem taxation, as a relevant factor for tacit collusion.

In the second part of the chapter, we focus on the impact of ad valorem and specific tariffs on collusion. As in the closed economy section, we adopt both grim trigger strategies and stick and carrots optimal punishments and derive the critical discount factors sustaining full collusion. The implicit collusive agreement consists, for each firm, in refraining from exporting into each other market. We show that, under grim trigger strategies, an ad valorem tariff is more collusion-enhancing that an equivalent specific tariff if and only if the revenue collected by the government through the protectionist instrument is sufficiently low, suggesting that specific tariffs are more efficient in the presence of relatively integrated markets. Under optimal punishments, an ad
valorem tariff is always more collusive enhancing that an equivalent specific tariff no matter the amount of revenue collected. These results seem in contrast with the conventional wisdom according to which ad valorem tariffs should be preferred to specific tariffs on welfare grounds.3

The effects of protectionist instruments such as tariffs and quotas on the stability of implicit collusive agreements have received little attention in the literature.4 Davidson (1984) analyzes the role of tariffs within a repeated quantity setting with homogeneous good showing that a small tariff leads to an industry structure more conducive to collusive behavior while large tariffs make collusion more difficult to sustain. Rotemberg and Saloner (1989) analyzes the effects of a quota and a tariff in a repeated price-setting oligopoly with one domestic and one foreign firm. Their main result is that the introduction of an import quota hinders cartel stability. This result is driven by the fact that a quota limits the foreign firm’s ability to punish, thus the home firm is more likely to cheat. Fung (1992) consider imperfect substitutes and quantity competition. He finds that when the foreign firm’s costs including the tariff are higher than the home firm’s costs, a reduction in tariffs may enhance collusion, implying an increase in the price level. Otherwise, lowering the tariff is always pro-competitive.5

It is well known that actual trade and tariff policy prefer ad valorem tariffs to specific tariffs. In the light of the results achieved in this chapter, in particular the collusive drawback of ad valorem tariffs, is it possible that the different impact on cartel stability is responsible for overturning the established welfare ranking? If so, from a policy perspective, a careful

---

3Helpman and Krugman (1989) address the non-equivalence of ad valorem to specific tariffs dealing with situations of monopoly or oligopoly. Kowalczuk and Skeath (1994) show that, in a setting where a country faces one foreign monopolist, ad valorem tariffs are welfare superior to specific tariffs. The result is driven by the fact that the ad valorem tariff is superior in terms of revenue extraction. In a dynamic two-country game, Lockwood and Wong (2000) show that the move from specific tariffs to ad valorem tariffs improves welfare in at least one country. Their results are driven by the superiority of ad valorem tariffs in terms of revenue generation.

4Neary and Leahy (2000) characterize optimal trade and industrial policy in dynamic oligopolistic markets. They consider a market with two firms, denoted "home" and "foreign", which compete over an indefinite, though finite, number T of time periods, allowing firms to make commitments in advance. Provided that T is finite, the possibility of collusion between firms is ruled out. For a characterization of optimal revenue-constrained trade and industrial policy towards dynamic oligopolies see Neary and Leahy (2003).

5Davidson (1984), Rotemberg and Saloner (1989) and Fung (1992), they all deal with the case where home and foreign firms compete only in the home market. We study a situation where home and foreign firms can compete in each others markets. This is an important distinction.
evaluation of the short and long run consequences implied by the use of different protectionist instruments is needed.

The remainder of this chapter is structured as follows: Section 3.2 focuses on closed economy while Section 3.3 deals with the open economy scenario. In particular, a comparison in terms of collusive outcome between the two types of commodity taxation and the two types of tariffs is presented at the end of Section 3.2 and Section 3.3 respectively. Concluding remarks are in Section 3.4.

3.2 Closed Economy

3.2.1 The Model

Consider two firms selling perfect substitute products and competing in quantities over an infinite time horizon. For the sake of simplicity, let the market demand be linear, \( p = 1 - X \), with \( p \) and \( X \) denoting price and industry output respectively. The total tax paid by firm \( i = \{1, 2\} \) under specific taxation corresponds to \( t_s x_i \), where \( t_s \) is the percentage of taxation to be paid on the amount of production \( x_i \). The impact (at the margin) of the introduction of a specific tax is clearly constant, in that the tax rate does not depend on the amount being produced, implying that specific taxation does not affect the decision upon cartelization. Things are more involved as far as an ad valorem tax is concerned. The total tax to be paid by firm \( i \) corresponds to \( t_v x_i p \), implying that the marginal tax rate turns out to be \( t_v M R \), where \( t_v \) is the ad valorem tax and \( M R \) stands for marginal revenue. Since profits maximization yields \( MR(1 - t_v) = MC \), \( MC \) being the marginal cost of production, the marginal tax rate can be rewritten \( [t_v/(1 - t_v)] MC \). The implication is that when the marginal cost of production is variable, the total amount of ad valorem tax to be paid by firm \( i \) depends on firm \( i \) and firm \( i \)'s behavior. Therefore, while specific taxation does not affect the stability of collusion (through the critical discount factor), ad valorem taxation does affect the incentives for firms to take part in implicit cartels.
In order to determine whether or not an ad valorem tax enhances the stability of implicit collusion among oligopolistic firms, we assume that the second order derivative of the cost function w.r.t. the level of production differs from zero, that is, we assume a variable unit cost. For the sake of simplicity let the marginal cost of producing the good be linear, $MC = \alpha + \beta x_i$, where $\alpha$ and $\beta$ are constants and $x_i$ denotes the quantity produced by firm $i = \{1, 2\}$. Notice that $\beta$ is the slope of the marginal cost, implying that returns to scale are decreasing (increasing) if $\beta > (<)0$.

We model firms interaction in the marketplace as a repeated quantity game over an infinite time horizon. We follow the standard set-up of infinitely repeated games. Tacit collusion implies that both firms agree to engage in a collusive agreement, according to the outcome of joint profit maximization. As usual in the literature, the focus is on the Pareto (from firms' viewpoint) optimal equilibrium (see Tirole, 1988, p. 247).

At any period, each firm may find it profitable to defect from the implicit agreement, being aware of the fact that its defection will cause future retaliation by the firm being cheated. The repeated game literature has traditionally considered two different kinds of punishments: Nash reversion (Friedman, 1971) and the more severe s.c. optimal punishments dating back to Abreu (1986). Optimality comes from the fact that if firms adhere to them, then the scope for collusion is maximized.

In the comparison between ad valorem and specific taxation in terms of critical discount factors, we first adopt the traditional grim trigger strategies, then we assume that firms follow stick and carrots optimal punishments. The rationale of using both types of punishment strategies is to derive results on the impact of different forms of commodity taxation on cartel stability independently of any particular assumption related to firms' behavior during the punishment phase.

Throughout the chapter we focus on Cournot competition simply because with identical firms, Bertrand competition, homogeneity in products and increasing marginal costs, as shown in Dastidar (1995), the pure strategies Bertrand equilibrium is necessarily non-unique.
3.2.2 Ad Valorem Taxation

Parameter $t_v \in [0, 1)$ denotes the ad valorem tax levied on the imperfectly competitive industry at stake. The profit of firm $i = \{1, 2\}$ is then equivalent to $\pi_i = px_i (1 - t_v) - \alpha x_i - \beta x_i^2 / 2$.

When the two firms agree to collude, the aim of the implicit cartel consists in the maximization of joint profit, $\pi_1 + \pi_2$. The solution to the maximization problem yields the following level of quantity to be produced by each firm, $x^c = (1 - t_v - \alpha) / \beta + 4 (1 - t_v)$. By plugging $x^c$ into the definition of individual profits, we obtain the per firm collusive profits:

$$\pi^c = \frac{(1 - t_v - \alpha)^2}{2[\beta + 4 (1 - t_v)]}$$  \hspace{1cm} (3.1)

Notice that the derivative of $\pi^c$ w.r.t. $t_v$ is always negative, implying that, ceteris paribus, an increase in the level of ad valorem taxation makes collusion less profitable and in turn it reduces the stability of implicit collusion. However, in order to assess the total effects of an ad valorem tax on cartel stability, we have to determine the profits accruing to the firm that breaks down the implicit agreement as well as the profits that each firm obtains during the punishment phase.

If, at time $t$, firm $i$ deviates from the collusive agreement, firm $j$ will detect the deviation only at the beginning of time $t + 1$, before implementing the punishment strategy. Hence, in the deviation period, the firm being cheated sticks to the cooperative strategy $x^c$. The maximization of $\pi_i$ subject to the condition that $x_j = x^c$ yields the optimal level of quantity to be sold during the deviation phase, which can be used to derive the expression of profits accruing to the deviating firm at time $t$:

$$\pi^d = \frac{(1 - t_v - \alpha)^2}{2[\beta + 4 (1 - t_v)]}$$  \hspace{1cm} (3.2)

The effects of $t_v$ on $\pi^d$ depend on the interplay between the two parameters in a complex

\footnote{Second order conditions are satisfied if $\beta > -2(1 - t_v)$.}
manner. As to the computation of punishment profits, we have to distinguish according to the type of punishment strategies adopted by firms.

**Grim trigger strategies**

Under grim trigger strategies, after any deviation at time $t$, each firm adopts the one-shot Nash equilibrium strategy from time $t + 1$ onwards. Simple computations lead to the following punishment quantity, $x^N = (1 - t_v - \alpha)/[\beta + 3(1 - t_v)]$. The resulting Nash equilibrium profits obtain:

$$
\pi^N = \frac{(1 - t_v - \alpha)^2 [\beta + 2(1 - t_v)]}{2 [\beta + 3(1 - t_v)]^2}
$$

(3.3)

Now we proceed to determining the critical discount factor associated with grim trigger strategies under ad valorem taxation. By plugging the relevant expressions into the definition of the critical discount factor $\delta^k = (\pi^d - \pi^c)/(\pi^d - \pi^N)$, with $k = \{v, s\}$, we get:

$$
\delta^v = \frac{[\beta + 3 (1 - t_v)]^2}{2\beta^2 + 12\beta (1 - t_v) + 17 (1 - t_v)^2}
$$

(3.4)

Notice that the critical discount factor depends upon the slope of the marginal cost and the level of taxation. In order to assess the impact of an ad valorem taxation on the stability of implicit collusion, we differentiate the critical discount factor w.r.t. $t_v$:

$$
\frac{\partial \delta^v}{\partial t_v} = -\frac{2\beta [\beta + 3 (1 - t_v)] (1 - t_v)}{[2\beta^2 + 12\beta (1 - t_v) + 17 (1 - t_v)^2]^2}
$$

(3.5)

Since the above derivative is always negative, and provided that the scope for collusion is measured by the area above the critical discount factor, we can write:

**Lemma 2** Under grim trigger strategies, if decreasing returns to scale prevail, the higher the level of ad valorem taxation, the larger the scope for collusion between firms. Otherwise, the opposite holds true.
Optimal punishments

In this subsection, we compute the critical discount factor implied by optimal punishments in the case of ad valorem taxation.

During a symmetric punishment period, the profit accruing to each firm:

$$\pi^{op} = (1 - t_v) (1 - 2x^{op}) x^{op} - \alpha x^{op} - \beta (x^{op})^2 / 2$$ (3.6)

In order to compute the optimal deviation from the punishment phase, the cheating firm, say firm $i$, has to solve the problem of maximizing $\pi_i$ w.r.t. $x_i$ subject to the constraint $x_j = x^{op}$. Simple computations lead to:

$$\pi^{dop} = \frac{(1 - t_v - \alpha)^2 (1 - \bar{x})^2}{2 (2 - 2t_v + \beta)}$$ (3.7)

By following Abreu (1986, Theorem 15), we get (see Chapter 1 for details):

$$\delta_v^o = \frac{(3 + \beta - 3t_v)^2}{4 (4 + \beta - 4t_v) (2 + \beta - 2t_v)}$$ (3.8)

We are interested in analyzing the impact of an ad valorem tax on the stability of implicit collusion. Proceeding as before:

$$\frac{\partial \delta_v^o}{\partial t_v} = -\frac{\beta (3 + \beta - 3t_v) (1 - t_v)}{2 (-4 - \beta + 4t_v)^2 (-2 - \beta + 2t_v)^2}$$ (3.9)

Since the above derivative is always negative (positive) if $\beta > (<) 0$, we can write:

**Lemma 3** Under optimal punishments, if decreasing returns to scale prevail, the higher the level of ad valorem taxation, the larger the scope for collusion between firms. Otherwise, the opposite holds true.
3.2.3 Specific Taxation

Parameter $t_s \in [0,1]$ denotes the specific tax levied on the imperfectly competitive industry. The profits of firm $i = \{1,2\}$ are then equivalent to $\pi_i = (p - t_s)x_i - \alpha x_i - \beta x_i^2 / 2$.

During the collusive phase, as for ad valorem taxation, the aim of the implicit cartel is to maximize industry profit. The optimal quantity produced by each firm adhering to the collusive agreement turns out to be $x^c = (1-t_s-\alpha)/(\beta+4)$, which implies the following per firm collusive profits:

$$\pi^c = \frac{(1-t_s-\alpha)^2}{2(\beta+4)}$$

(3.10)

It is immediate to see that $\pi^c$ is decreasing in the level of taxation; hence, ceteris paribus, an increase in $t_s$ reduces the profits of implicit collusion.

The optimal deviation from the collusive path can be easily computed as before: the cheating firm decides its optimal deviation quantity, taking into account that its rival’s production at time $t$ corresponds to the collusive level. The resulting deviation profits are:

$$\pi^d = \frac{(1-t_s-\alpha)^2 (3+\beta)^2}{2(2+\beta)(4+\beta)^2}$$

(3.11)

Grim trigger strategies

During the punishment phase, each firm adopts the Cournot-Nash equilibrium strategy. Simple computations lead to: $x^N = (1-t_s-\alpha)/(3+\beta)$. Nash profits amount to:

$$\pi^N = \frac{(1-t_s-\alpha)^2 (\beta+2)}{2(3+\beta)^2}$$

(3.12)

The critical discount factor associated with grim trigger strategies under specific taxation is

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8Second order conditions are satisfied if $\beta > -2$. 

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obtained by plugging the relevant profits expressions into $\delta^g_i$:

$$\delta^g_i = \frac{(\beta + 3)^2}{2\beta^2 + 12\beta + 17} \tag{3.13}$$

Notice that, in case of specific taxation, the critical discount factor does not depend on $t_s$.

**Lemma 4** Under grim trigger strategies, the level of specific taxation does not affect the scope for collusion.

**Optimal punishments**

The symmetric per period punishment profits write:

$$\pi^{op} = (1 - 2x^{op} - t_s) x^{op} - \alpha x^{op} - \beta (x^{op})^2 / 2 \tag{3.14}$$

The optimal deviation from the punishment strategy by firm $i$ is the outcome of the maximization of $\pi_i$ w.r.t. $x_i$ subject to the condition that firm $j$ sticks to $x^{op}$. As a result:

$$x^{dop} = \frac{(1 - t_s - \alpha - x^{op})^2}{2(2 + \beta)} \tag{3.15}$$

By following Abreu (1986, Theorem 15), we get the expression of the critical discount factor associated with optimal punishments under specific taxation:

$$\delta^o_s = \frac{(3 + \beta)^2}{4(2 + \beta)(4 + \beta)} \tag{3.16}$$

Notice that, as before, the critical discount factor does not depend on $t_s$.

**Lemma 5** Under optimal punishments, the level of specific taxation does not affect the scope for collusion.
3.2.4 Comparison

We first compare the effects of ad valorem and specific taxation on cartel stability in case firms follow grim trigger strategies during the punishment phase. Notice that, by (3.4) and (3.13), $\delta^s$ is equivalent to $\delta^p$ under the parameter restriction $t_v = 0$. It suffices to use Lemma 2 and Lemma 4 to reach the conclusion that, as long as $\beta > 0$, $\delta^p < \delta^s$ for every level of taxation. Otherwise, if $\beta < 0$ then $\delta^p > \delta^s$ for every level of taxation. Similarly, by (3.8) and (3.16), with optimal punishments, $\delta^s$ is equivalent to $\delta^o$ under the parameter restriction $t_v = 0$. Thanks to Lemma 3 and Lemma 5, we reach the same qualitative conclusions as under Nash reversion. Therefore, since the scope for collusion is measured by the range of values above the critical discount factor, we can state:

**Proposition 8** For any $t_v$ and $t_s$, no matter if firms adopt grim trigger strategies or optimal penal codes during the punishment phase, if decreasing returns to scale prevail, then ad valorem taxation implies a larger scope for collusion than specific taxation. Otherwise, if technology exhibits increasing returns to scale, the opposite holds true.
The following figure illustrates the above proposition in case of grim trigger strategies.\(^9\) The same kind of figure applies to optimal punishments. \(\beta < 0\)

3.3 Open Economy

3.3.1 The Model

Two firms, firm \(a\) located in country \(A\) and firm \(b\) located in country \(B\), are engaged in quantity (Cournot) competition over an infinite time horizon.\(^{10}\) Let \(x_i\) and \(x_i^*\) denote the output that firm \(i = \{a, b\}\) produces for domestic and foreign consumption, respectively. In each country,

\(^9\)Notice that, from s.o.c., the admissible parameter range is \(t_v < 1 + \beta/2\). Hence, with \(\beta > 0\) there are no restrictions, while with \(\beta < 0\) the maximum value of \(t_v\) is always lower than one.

\(^{10}\)We follow a partial equilibrium approach. International trade policy in general equilibrium models are widely discussed in Anderson and Neary (2005).
the inverse demand function is given by:

\[ p_j = 1 - X_j, \quad j = \{A,B\} \]  

(3.17)

where \( X_A = x_a + x_a^* \) and \( X_B = x_b + x_b^* \) stand for industry output in country A and B, respectively. On the supply side, we assume constant returns to scale for the sake of simplicity. Furthermore, since cartel stability is not affected, we normalize the constant unit cost to zero without any loss of generality. When the two firms agree to collude, the aim of the implicit cartel consists in the maximization of joint profit, \( \pi_a + \pi_b \). For each firm, collusion is enforced by the understanding to stay in her own domestic market, acting like a monopolist. Unlike in the previous chapter, no collusive trade arises. Therefore the per firm collusive profit is \( \pi^c = 1/4 \).

### 3.3.2 Ad Valorem Tariffs

Parameter \( \tau_v \in [0,1/2] \) stands for an ad valorem tariff levied on firm \( i = \{a,b\} \) profits from exports. Then firm \( a \)'s total profit is \( \pi_a = (1 - x_a - x_b^*) x_a + (1 - \tau_v) (1 - x_a^* - x_b) x_a^* \). Analogously for the other firm \( b \).

#### Grim Trigger Strategies

If, at time \( t \), firm \( i \) deviates from the collusive agreement, her rival will detect the deviation only at the beginning of the subsequent period before implementing the punishment strategy. Hence, as in the closed economy case, during the deviation period, the firm being cheated continues to play the cooperative strategy. Straightforward computations yields the following expression of deviation profits:

\[ \pi^d_v = \frac{(5 - \tau_v)}{16} \]  

(3.18)

Under grim trigger strategies, after any deviation, each firm adopts the one-shot Nash equilibrium strategy from time \( t + 1 \) onwards. The punishment quantity is \( x_v^N = 1/3 \) and the
resulting Nash equilibrium profits amount to:

$$\pi^N_N = \frac{(2 - \tau_v)}{9}$$  \hfill (3.19)

Note that $\pi^d > \pi^c > \pi^N$. Hence, the game turns out to be a Prisoner’s dilemma. We are now able to derive the critical discount factor associated with grim trigger strategies under ad valorem tariff. By using the relevant profit expressions and the definition of the critical discount factor we get:

$$\delta^N_{oe} = \frac{9(1 - \tau_v)}{13 + 7 \tau_v}$$  \hfill (3.20)

where the subscript oe means open economy.

**Optimal Punishments**

By proceeding as in the closed economy section, we compute the critical discount factor generated by optimal punishment rules. During the punishment phase, each firm plays $x_{v}^{op}$, both at home and abroad. The corresponding punishment profit obtains:

$$\pi_{v}^{op} = (1 - 2x_{v}^{op})x_{v}^{op} + (1 - \tau_v) (1 - 2x_{v}^{op}) x_{v}^{op}$$  \hfill (3.21)

As to the optimal deviation from the punishment phase, the cheating firm, say firm $i$, has to solve the problem of maximizing $\pi_i$ w.r.t. $x_i$ subject to the constraint that the firm being cheated continues to play the prescribed penal code, i.e. $x_j = x_{v}^{op}$. The maximization problem yields the following optimal deviation profit:

$$\pi_{v}^{dep} = \frac{(2 - \tau_v) (1 - x_{v}^{op})^2}{4}$$  \hfill (3.22)
By following Abreu (1986, Theorem 15), we get:

\[
\delta_{tec}^a = \frac{9 (1 - \tau_v) \left(3 + 2\tau_v - 2\sqrt{2 - 3\tau_v + \tau_v^2}\right)}{4 + 96\tau_v}
\]  

(3.23)

and the resulting optimal quantity to be played in the punishment phase is:

\[
x_{v}^{op} = \frac{1}{3} + \frac{1 - \tau_v}{6\sqrt{2 - 3\tau_v + \tau_v^2}}
\]  

(3.24)

Note that \(x_v^{op}\) is higher than the Nash equilibrium quantity, implying that the punishment price is lower than under grim trigger strategies. It is easy to check that the punishment profit generated by the use of optimal punishments is always lower than the one associated to infinite Nash reversion. This amounts to saying that Abreu’s punishments turn out to be harsher than grim trigger strategies.

3.3.3 Specific Tariffs

Parameter \(\tau_s \in [0, 1/2]\) stands for a specific tariff levied on firm \(i = \{a, b\}\) exports. Then firm \(a\)'s total profit is equivalent to \(\pi_a = (1 - x_a - x_a^*)x_a + (1 - x_a^* - x_b - \tau_s)x_a^*\). Analogously for the other firm \(b\).

Grim Trigger Strategies

Firm \(i\)'s profit from a deviation from the collusive agreements is:

\[
\pi_i^d = \frac{5 - 4(1 - \tau_s)\tau_s}{16}
\]  

(3.25)

After a deviation is detected, say at time \(t\), both firms revert to the one-shot Nash equilibrium strategy from time \(t + 1\) onwards. Under specific tariff, the punishment quantities \(x_s^N = 1 + \tau_s/3\) and \(x_s^{*N} = 1 - 2\tau_s/3\) are played at home and abroad respectively. The Nash
equilibrium profits:
\[ \pi^N_s = \frac{2 - \tau_s(2 - 5\tau_s)}{9} \] (3.26)

It is easy to check that \( \pi^d_s > \pi^c > \pi^N_s \). The expression of the critical discount factor sustaining full collusion is the following:
\[ \delta^g_{soc} = \frac{9(1 - 2\tau_s)}{13 + 22\tau_s} \] (3.27)

**Optimal Punishments**

During the punishment phase, each firm plays \( x_s^{op} \), both at home and abroad. The symmetric punishment profit accruing to each firm:
\[ \pi_s^{op} = (1 - 2x_s^{op})x_s^{op} + (1 - 2x_s^{op} - \tau_s)x_s^{op} \] (3.28)

As before, optimal deviation from the punishment phase can be easily computed by considering that the cheating firm, say firm \( i \), maximizes \( \pi_i \) w.r.t. \( x_i \) subject to the constraint \( x_j = x_s^{op} \).

Simple computations lead to:
\[ \pi_s^{op} = \frac{(2 - 2x_s^{op} - \tau_s)^2}{8} \] (3.29)

By following Abreu (1986, Theorem 15), we get:
\[ \delta^c_{soc} = \frac{9(1 - \tau_s)}{4 \left( 3 + (2 - \tau_s) \sqrt{2(1 - \tau_s) + 6\tau_s - 2\tau_s^2} \right)} \] (3.30)

and the resulting optimal quantity to be played in the punishment phase is:
\[ x_s^{op} = \frac{1}{3} + \frac{\sqrt{2(1 - \tau_s) - 2\tau_s}}{12} \] (3.31)
3.3.4 Comparison

Here we proceed with a comparison between ad valorem and specific tariffs in terms of cartel stability. The aim is to assess which of the two forms of tariffs is more likely to induce the undesired effect of enhancing the sustainability of an implicit collusive agreement consisting in refraining from exporting into each other market.

We have already computed, for each type of tariff, the critical discount factor sustaining full collusion. However, for a comparison to be meaningful, (3.20) and (3.27) under grim trigger strategies and (3.23) and (3.30) under optimal punishments must be compared for an equal amount of revenue collected.\(^{11}\) When the government in country A imposes ad valorem tariffs, the revenue collected amounts to \(\tau_A p_A x_A^*\) and similarly for country B. When instead the same government relies on specific tariffs, the revenue collected amounts to \(\tau_s x_b^*\) and similarly for country B.

**Grim trigger strategies**

By plugging the corresponding expressions into the revenue definitions, the same amount of revenue in each country is generated if and only if:

\[
\tau_v = 3\tau_s (1 - 2\tau_s)
\]  

(3.32)

By using (3.32), (3.20) and (3.27), the two relevant critical discount factors are:

\[
\delta^{grc}_{voc} = \frac{9 (1 - 3\tau_s + 6\tau_s^2)}{13 + 21\tau_s (1 - 2\tau_s)}; \quad \delta^{grc}_{soc} = \frac{9 (1 - 2\tau_s)}{13 + 22\tau_s}
\]  

(3.33)

\(^{11}\)Alternatively, the comparison could be performed under the condition that the two types of tariffs have the same (equivalent) effect on imports. However, the qualitative results of the analysis seem not to be affected by the nature of the comparison.
where the superscript $re$ stands for revenue equivalent. The figure below plots $\delta_{\text{re}}^{\text{voc}}$ and $\delta_{\text{soc}}^q$:

Fig. 3.2: $\delta_{\text{re}}^{\text{voc}}$ vs $\delta_{\text{soc}}^q$

**Proposition 9** Under grim trigger strategies, an ad valorem tariff is more collusion-enhancing than an equivalent specific tariff if and only if $\tau_s < 0.12$, otherwise the opposite holds true.

The implication of the above proposition is that for low levels of generated revenue a specific tariff should be favored over an ad valorem tariff producing the same revenue if the objective of the trade policy coincides with the objective of the competition policy of reducing the occurrence of implicit collusion in international markets. Provided that the process of economic integration is accompanied by a general reduction in tariffs and other trade costs, a specific tariff seems to be more effective than an equivalent ad valorem tariff in collecting a given amount of revenue. These results seem in contrast with the conventional wisdom according to which ad valorem tariffs should be preferred to specific tariffs on welfare grounds. Once the possibility of repeated interaction is taken into account, ad valorem tariffs could have a collusive drawback which can
be captured only within a dynamic setting.

**Optimal punishments**

By plugging the corresponding expressions into the revenue definitions, the same amount of revenue in each country is generated if and only if $\tau_v = f(\tau_s)$. The two relevant critical discount factors $\delta^o_{voe}\big|_{\tau_v=f(\tau_s)} = \delta^o_{voie}$ and $\delta^o_{soe}$ are depicted in the following figure:

![Graph showing $\delta^o_{voie}$ vs $\delta^o_{soe}$](image)

Since $\delta^o_{voie} < \delta^o_{soe}$ for any $\tau_s$, we are in a position to state:

**Proposition 10** Under optimal punishments, an ad valorem tariff is always more collusion-enhancing that an equivalent specific tariff.

The implication of the above proposition is that when firms adopt optimal punishments for

\[\text{footnote text} \]
any level of revenue collected, specific tariffs are always more efficient than ad valorem tariffs given that they are associated with a lower likelihood of collusive agreements.

### 3.4 Concluding Remarks

The analysis here has focused on the comparison between ad valorem and specific taxation and tariffs in terms of cartel stability. We have adopted a standard two-firm quantity competition model to compute analytically, in each fiscal regime and tariff regime, the critical discount factor, i.e. the minimum discount factor such that collusion can be sustained as an equilibrium outcome of firms' repeated interactions. Throughout the chapter we have considered two types of punishment strategies: grim trigger strategies and stick and carrots optimal punishments. The former imply that the punishment phase is represented by firms permanently reverting to the one shot Nash equilibrium strategy, while the latter require that the firm being cheated punishes itself in order to punish the defector until both firms revert to the prescribed penal code. The important difference is given by the fact that punishment under the stick and carrot strategy is more severe than under a trigger strategy, but punishment is followed by a resumption of tacitly collusive output restriction (see Martin, 1993). The rationale of using both types of punishment strategies has been to derive results on the impact of different forms of commodity taxation and tariffs on cartel stability independently of any particular assumption related to firms' behavior during the punishment phase.

In the first part of the chapter, the closed economy section, we have shown that, no matter the type of punishment being adopted, under ad valorem taxation, in the case of increasing unit cost, the higher the level of taxation, the easier it is for firms to sustain an implicit collusive agreement; in the case of decreasing unit cost, the opposite holds true. Furthermore, we have shown that under specific taxation the incentives for firms to take part in implicit cartels are not affected by the level of per unit tax.

In the second part of the chapter, the open economy section, we show that when firms
revert to the one shot Nash equilibrium strategy during the punishment phase, an ad valorem tariff fosters collusion more than a specific tariff generating the same revenue if and only if the revenue collected is sufficiently low. When instead firms adopt optimal punishments, an ad valorem tariff is always more collusion-enhancing that an equivalent specific tariff no matter how much revenue is collected.

Our theoretical predictions could be easily extended in various directions. Further research is needed to explore the implication of partial instead of full collusion, partial collusion meaning that firms collude without reaching joint profit maximization. Another interesting possibility is to determine the optimal combination of ad valorem and specific taxation/tariffs such that the scope for collusive agreements is minimized. Finally, it could be relevant to abandon the homogeneity assumption in order to study the interplay between product differentiation, the nature of commodity taxation/tariffs and price competition in terms of cartel stability.
Chapter 4

Optimal Corporation Tax: an I.O. approach

4.1 Introduction

In this chapter we resurrect an important debate on the relationship between optimal corporation tax and market power that dates back to Schumpeter (1942) and Galbraith (1973). Galbraith felt that highly concentrated industries should be taxed heavily. Corporate taxation could be used to alleviate monopolistic power. Schumpeter presents us with the opposing view and emphasizes the drawbacks of taxing powerful industries heavily. In his view, corporation taxes can create distortions in the dynamics of the industry evolution and can reduce social welfare in the long run.

The existing game theoretic models of imperfect competition add little to this debate. The reason for this is that any (proportional) tax on profits, in the short-run (fixing the number of companies), does not affect the first order conditions of profit maximization. Equilibrium prices and quantities are the same with and without taxes on profits, so the arguments that corporation taxes should be used in order to mitigate monopolistic power seem not to be

\footnote{This chapter is based on a joint work with Luca Colombo and P. Paul Walsh.}
relevant. Moreover, if the revenue collected by the government becomes public spending, and consumers and firms are weighted equally in the welfare function, corporation taxes are also welfare neutral. Indeed, within a traditional oligopoly model, there seems to be no reason to analyze the effects of corporate taxation.²

In this chapter, using a Sutton (1991) approach to industry evolution, we investigate how optimal corporation tax should be designed in reaction to industry specific sunk costs in long run equilibrium. We first write down a general oligopoly model to show that optimal profit taxation is negatively related to industry specific sunk costs once some degree of monopolistic power survives in long run equilibrium. We then illustrate our point with an example considering a Cournot oligopoly game at the long run equilibrium. Within a Cournot oligopoly, Von Weizsäcker (1980) shows that the long run equilibrium number of firms may exceed the socially optimal number of firms.³ A forward looking government will regulate entry in a way that is socially desirable with corporate taxation. In the short run, taking the number of companies as a given, profit tax has a neutral effect on quantity and price outcomes in oligopoly. However, corporation tax has implications for the evolution of market structure, a point neglected by the existing academic literature. Clearly, the number of firms operating in long run equilibrium can be affected by the level of profit taxation. Such dynamics, if understood by a perfectly informed forward looking government, should be taken into account in the design of optimal corporation tax.⁴ By focussing on the influence of corporation tax on market structure, our study shows that industries characterized by high sunk costs, which are ceteris paribus, linked

²The existing literature on taxation in oligopoly focuses on the different forms of commodity taxation, ad valorem and specific (see Kay and Keen, 1983; Delipalla and Keen, 1992; Anderson et al., 2001, inter alia), without taking into consideration taxation on profits. The focus of our analysis is on profit (or corporation) tax in isolation simply because, despite its relevance in the real world, there are no works on the subject under imperfect competition (due to the short-run equilibrium neutrality).
³See also Martin (1984), Mankiw and Whinston (1986), Suzumura and Kiyono (1987). The tendency toward excessive entry in Cournot equilibrium is due to the "business stealing" effect. In such markets, the profit maximizing entry decision of individual firms does not consider the negative externality that entry imposes on incumbent firms. The resulting equilibrium number of firms is excessive from a social point of view.
⁴In case of commodity taxation, the issue of entry in oligopoly has been considered in Auerbach and Hines (2002), based on earlier work by Seade (1980a; 1980b), Besley (1989), Myles (1989), Delipalla and Keen (1992) and de Meza, Maloney and Myles (1995).
to concentrated industries, should be taxed softly. On the contrary, when sunk costs are low, the opposite holds true. The principle of taxation highlighted in this chapter is analogous to that found in Ramsey (1927) pricing. The interaction of imperfect competition, strategic reactions of players in the industry, with policy instruments, can create large distortions as a by product of government intervention. The more monopolistic power in an industry the bigger these distortions. Hence a forward looking government is forced to internalize this and will tax industries with higher sunk costs (monopolistic power) less. In our empirical section we provide suggestive evidence that this Schumpeterian (1942) principle of taxation was used in France, Italy and the UK in the 90s.

4.2 Theory

4.2.1 The Model

The economy is composed by $M$ industries. The inverse market demand in industry $j = \{1, 2, 3, \ldots, M\}$ is given by a function $p_j : R_+ \to R_+$, with $p_j < 0$. Every firm operating in industry $j$ is assumed to possess the same production technology exhibiting constant returns

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5 Our theory will predict different rates of taxation for different industries. In reality, corporation tax rate is the same for all industries. Nonetheless effective corporation tax rates differ across industries. This results from heterogeneity in the take up of tax allowances, exemptions, and exclusions designed by government.

6 Walsh and Whelan (1999) highlight the dangers of government policy (ban on loss leading in supermarkets) that try to move industries from second towards first best outcomes in the presence of endogenous imperfect competition. The interaction of imperfect competition, strategic reactions of players in the industry, with policy instruments, if unanticipated, can move the economy back to a third best outcome.

7 In large economies the majority of tax income from corporate taxation come from large indigenous industries. For this reason we are happy to focus on an industry specific explanation for differences in effective corporation taxation. Vandenbussche and Tan (2005), focusing on company specific effects, show that foreign owned companies have more favorable effective corporate taxation relative to home companies. They show how multinationals can use outside options to bargain down taxation with local governments. Allowing for open economy considerations in the design of corporation taxes would be an interesting extension to our framework. We feel that tax competition over interregional or international investment flows would reinforce the incentive to tax high sunk cost industries ever softer. There are many US and European studies that measure the sensitivity of investment flows to corporate taxation. Deasi et al (2002), Hines (1996), Grubert and Mutti (1991) and Alshuler et al (1998). In addition, there may be an interesting interaction of open economy considerations and industry specific tax allowances and exceptions that would have implications for the financing of multinational corporations. One nice thing about our set-up is that we do have an outside option in the model which could be easily used to address the issue of (international) tax competition. We feel that cross border competition would reinforce our results.
to scale; \( k_j \geq 0 \) is the unit cost of production. Industry \( j \)'s output is \( Q_j = \sum_{i=1}^{n_j} q_{ij} \), where \( q_{ij} \) represents the quantity produced by firm \( i = \{1, 2, 3, ..., n_j\} \) in the \( j \)-th industry. Gross operative profits (before tax) for a generic firm in industry \( j \) are then given by:

\[
\pi_{ij} = (p_j - k_j) q_{ij} \quad (4.1)
\]

In every industry, the government imposes a proportional corporate income tax \( \tau_j \in [0,1) \) on each firm's operating profits. Net profits (after tax) correspond to \( (1 - \tau_j) \pi_{ij} \). For each firm entering industry \( j \), there is an entry (set up) sunk cost equal to \( F_j > 0 \). Once in the market, the firm \( i \)'s problem consists in setting \( q_{ij} \) so as to maximize its profits. The first order condition of firm \( i \)'s problem turns out to be (assuming an inner solution exists):

\[
(1 - \tau_j) \left[ p_j (1 + \theta_j) q_{ij} + p_j - k_j \right] = 0 \quad (4.2)
\]

where \( \theta_j = dQ_{-ij}/dq_{ij} \), as in Bresnahan (1989), takes on a value between zero and one. It determines how much marginal revenue falls due to price competition increasing as output expands. If we define \( \lambda_j = 1 + \theta_j \), \( \lambda_j \in [0, n_j] \) captures firms' strategic interactions in industry \( j \). With \( \lambda_j = 0 \), conjectures are competitive in industry \( j \); \( \lambda_j = 1 \) corresponds to Cournot conjectures and \( \lambda_j = n_j \) corresponds to tacit collusion in industry \( j \).

Notice that in (4.2) the term \( 1 - \tau_j \) can be canceled out, meaning that the profit maximizing quantity chosen by each firm does not depend on \( \tau_j \) for any given \( n_j \). Let \( q^*_j(n_j, k_j, \lambda_j) \) denote the symmetric equilibrium quantity and \( \pi^*_j(n_j, k_j, \lambda_j) \) denote the equilibrium operative profits, both depending on the number of firms, the level of production costs in industry \( j \) and the conjectures parameter.

A firm will find it profitable to enter industry \( j \) if and only if:

\[
\Pi^*_j = (1 - \tau_j) \pi^*_j - F_j \geq \Pi
\quad (4.3)
\]
where $\Pi \geq 0$ is the outside option. Without any loss of generality, we normalize the exogenously given outside option to zero. We look at the equilibrium with free entry. Under the assumption of free entry, $\Pi^*$ is driven to zero meaning that the entry process stops when all the industry specific profit opportunities have been exploited. Since this is true for all industries, no matter where a firm decides to enter, the equilibrium profit will correspond to the outside option. By solving (4.3) for $\pi^*_j$, we get:

$$\pi^*_j = \frac{F_j}{1 - \tau_j}$$

Clearly, this entry condition will drive a negative relationship between $n_j$, via equilibrium profits $\pi^*_j(n_j)$, and both the level of fixed cost and the corporation tax. The revenue collected by the government in industry $j$, which amounts to $n_j\tau_j\pi^*_j$, is supposed to be entirely spent in a productive way.\(^8\) Accordingly, the overall government spending that results is written down as:

$$G = \sum_{j=1}^{M} n_j\tau_j F_j$$

In the equilibrium with free entry, social welfare is given by:

$$W = G + CS$$

where $CS = \sum_{j=1}^{M} CS_j$ is the aggregate consumers' surplus, with $CS_j$ equal to:

$$CS_j = \int_{0}^{Q_j} p_j(Q_j) dQ_j - Q_j p(Q_j)$$

We are interested in characterizing the optimal behavior of a forward looking government seeking to maximize social welfare. By definition, a forward looking government is able to anticipate the number of firms in each industry at the end of the entry process. Let $n^{f}_{j}(\tau_j, k_j, F_j, \lambda_j)$

\(^8\)This assumption is not crucial to the analysis. One can easily assume that a fraction $\lambda \in [0, 1]$ of $G$ is spent in a productive way.
stand for the number of firms operating in equilibrium in industry $j$ as a function of the level of corporation tax, unit cost of production, entry sunk cost and the conjectures parameter, such that the participation constraint (4.3) is just binding. In the long run we have:

$$G = \sum_{j=1}^{M} n_j^{\tau_j} (\ldots, \tau_j, \ldots) \frac{\tau_j}{1-\tau_j} F_j$$

$$CS_j = \int_0^{Q_j(n_j^{\tau_j})} p_j(Q_j(n_j^{\tau_j})) dQ_j - Q_j(n_j^{\tau_j}) p(Q_j(n_j^{\tau_j}))$$

The government's maximization problem writes:

$$\max_{\tau_1, \tau_2, \ldots, \tau_M} W = G + CS$$

$$\text{s.t. } \tau_j \in [0, 1] \text{ and } n_j = n_j^{\tau_j}$$

We are interested in determining the sign of $d\tau^*_j/dF_j$. By solving the above government's problem we get the following first order condition:\(^9\)

$$\frac{dW}{d\tau_j} = \frac{1}{(1-\tau_j)^2} \left\{ F_j n_j^{\tau_j} + (1-\tau_j) \frac{dn_j^{\tau_j}}{d\tau_j} \left[ F_j \tau_j + (1-\tau_j) \frac{dCS_j}{dQ_j} \frac{dQ_j}{dn_j^{\tau_j}} \right] \right\}$$

Hence:

$$\frac{dW}{d\tau_j} \propto \frac{F_j \left[ n_j^{\tau_j} + \tau_j (1-\tau_j) \frac{dn_j^{\tau_j}}{d\tau_j} \right] + (1-\tau_j)^2 \frac{dCS_j}{dQ_j} \frac{dQ_j}{dn_j^{\tau_j}}}{A}$$

$$\frac{dW}{d\tau_j} \propto \frac{(1-\tau_j) \frac{dCS_j}{dQ_j} \frac{dQ_j}{dn_j^{\tau_j}}}{B}$$

where $B$ is always negative while $A$ can take either sign.\(^10\) Of course, if $A$ turns out to be negative, then $dW/d\tau_j < 0$ implying that the optimal level of taxation is zero. To avoid a

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\(^9\)Throughout the chapter, second order condition are always satisfied. They are omitted for brevity.

\(^10\)Notice that consumers' surplus is increasing in industry output and that industry output is increasing in the number of active firms. Furthermore, by (4.4), the number of active firms in the industry is decreasing in the level of taxation in that industry.
corner solution, \( A \) must be positive. Let us define \( \phi_j = -\left( \frac{dn_j^L/d\tau_j}{\tau_j/n_j^L} \right) \) the elasticity of the number of firms in the long run w.r.t. the level of taxation. It measures the percentage decrease in the number of firms in the long run following by a percentage increase in the level of taxation: the higher \( \phi_j \), the higher is the impact of taxation on entry.

**Lemma 6** An inner solution to \( P \) exists as long as \( \phi_j < 1/(1 - \tau_j) \).

Not surprisingly, if the influence of taxation on entry is too strong, then the maximization of social welfare yields a zero corporation tax. Any strictly positive level of taxation would decrease social welfare compared to a no tax situation.

In order to assess the relationship between the level of optimal corporation tax (assuming Lemma 6 is satisfied) and the level of entry sunk costs in each industry, by using the implicit function theorem, we can write:

\[
\frac{d\tau_j^*}{dF_j} \propto \frac{dW}{d\tau_j dF_j} \tag{4.10}
\]

Since, without making any particular assumption on the functional forms it is not possible to sign (4.10), we consider that:11

- A1) in each industry, the inverse market demand is \( p_j = 1 - Q_j \);
- A2) once in the market, production entails no cost \( (k_j = 0) \);
- A3) firms compete a la Cournot \( (\lambda_j = 1) \).

After routine computations, the symmetric Nash equilibrium quantity produced by each firm turns out to be:

\[
q_j^* = \frac{1}{1 + n_j} \tag{4.11}
\]

---

11 Notice that \( d^2W/d\tau_j dF_j \propto n_j^L + A + B \) with 
\[
A = \frac{dn_j^L}{dF_j} \left( \frac{df_j}{df_j} \right)^2 \frac{d^2CS_j}{dQ_j^2} \frac{d^2Q_j}{d^2n_j^L} \]

\[B = (1 - \tau_j) \tau_j \frac{dn_j^L}{d\tau_j}.
\]
and the associated per firm Nash equilibrium net profits amount to:

$$\Pi_j^* = (1 - \tau_j) \left( \frac{1}{1 + n_j} \right)^2 - F_j$$

(4.12)

A firm decides to enter if and only if $\Pi_j^* \geq 0$. Under the assumption of free entry, $\Pi_j^*$ is driven to 0. By solving (4.12) for $n_j$, the resulting number of firms operating in industry $j$ in equilibrium with free entry obtains:

$$n_j^L = \sqrt[2]{\frac{1 - \tau_j}{F_j}} - 1$$

(4.13)

As a consequence, in each industry, the lower the corporation tax rate the higher the number of firms in the market. By choosing a small $\tau_j$ the government can induce more entry and vice versa. Hence, $\tau_j$ becomes a tool to regulate entry.

Using the definition of public spending (4.5) and aggregate consumers' surplus (4.7), social welfare can be written:

$$W = \sum_{j=1}^{M} \left[ n_j \left( \tau_j \frac{F_j}{1 - \tau_j} \right) + \frac{1}{2} \left( \frac{n_j}{1 + n_j} \right)^2 \right]$$

(4.14)

Since the government is forward looking, it is able to anticipate the effect of $\tau_j$ on the entry process in each industry correctly, implying that $n_j = n_j^L$. The government's maximization problem becomes:

$$\max_{\tau_1, \tau_2, \ldots, \tau_M} W = \sum_{j=1}^{M} \left[ \frac{1}{2} + F_j \left( 1 - \sqrt[2]{\frac{1 - \tau_j}{F_j}} - \frac{1}{2(1 - \tau_j)} \right) \right]$$

s.t. $\tau_j \in [0, 1]

The optimal solution to $P$ is given by:

$$\tau_j^* = 1 - \sqrt[2]{F_j}$$

(4.15)
which always satisfies second order conditions. Clearly, the relationship between $\tau^*_j$ and $F_j$ is negative.\footnote{The elasticity of $n^*_j$ with respect to $\tau_j$ evaluated at the optimum is $\varepsilon_j = 1/(2\sqrt{F_j})$.}

By plugging (4.15) into (4.13), the equilibrium number of firms operating in the long run equals:

$$n^*_j = \frac{1 - \sqrt[3]{F_j}}{\sqrt[3]{F_j}}$$  \hspace{1cm} (4.16)

By solving (4.16) for $F_j$, and by using symmetry, i.e. the fact that $1/n^*_j$ is the equilibrium market share of each firm in industry $j$, we get:

$$F_j = \frac{HHI_j^3}{(1 + HHI_j)^3}$$  \hspace{1cm} (4.17)

where $HHI_j = 1/n^*_j$ is the index of market concentration in industry $j$ (Herfindahl-Hirschman Index). Given that $\partial HHI_j/\partial F_j > 0$, the higher the sunk cost, the higher market concentration.

By plugging (4.17) into (4.15), the expression of optimal corporation tax can be rewritten:

$$\tau^*_j = \frac{1}{1 + HHI_j}$$  \hspace{1cm} (4.18)

The following figure illustrates the relationship between optimal corporation tax and market
concentration in industry \( j \).

In the equilibrium with free entry:

\[ p_j^L = \sqrt{F_j}; \quad Q_j^L = 1 - \sqrt{F_j} \] (4.19)

while welfare turns out to be:

\[ W_j^L = \sum_{j=1}^{M} \left[ \frac{\sqrt{F_j} + 2 (\sqrt{F_j})^4 - 3F_j}{2\sqrt{F_j}} \right] \] (4.20)

Notice that \( \lim_{F_j \to 0} W_j^L = M/2 \), with \( \partial W_j^L / \partial F_j < 0 \). The lower the barriers to entry, the higher the level of social welfare in presence of optimal corporation tax. It is worthy to remark that low barriers to entry are associated with high corporate taxation. In order to restrict entry in a socially desirable way, if \( F_j \to 0 \) then \( \tau_j^* \to 1 \).
Proposition 11 Under Cournot competition a high sunk cost in industry j (a high $HHI_j$) yields a low optimal corporation tax rate to be imposed in that industry.

Now, let us compare $n_j^{L*}$ with (4.13) when $\tau_j = 0$:

$$n_j^{NT} = \frac{1}{\sqrt{F_j}} - 1$$

(4.21)

where the superscript $NT$ stands for no tax. We can immediately verify that, $n_j^{L*} < n_j^{NT}$, i.e. the number of firms operating in the long run when an optimal corporation tax is introduced is lower than the number of firms that would have entered the market without taxation. We know from the existing literature that, in the absence of taxation, there is an excess of entry with respect to the second best solution.

4.2.2 Entry: second best solution

Let us characterize the second best solution of the entry process. We are about to show that by choosing the optimal level of corporation tax $\tau_j^*$ it is possible for the government to achieve the socially desirable number of firms in each industry. The government’s maximization problem writes:

$$\max_{n_1, n_2, \ldots, n_M} W^{SB} = \sum_{j=1}^{M} \left[ n_j \left( \pi_j^* - F_j \right) + CS_j \right]$$

s.t. $n_j \geq 1$

The optimal solution to $P$ is given by:

$$n_j^{SB} = \frac{1}{\sqrt{F_j}} - 1$$

(4.22)

which corresponds to $n_j^{L*}$.

Proposition 12 A forward looking government may influence the entry process in a way that is socially desirable. The second best solution is achieved by choosing $\tau_j^*$. 

70
We have shown that in the presence of forward looking governments, \( \tau_j \) can be used in order to regulate the entry process in a socially desirable way. In the next section we will investigate whether the empirical relationship between market concentration and corporation tax is consistent with the principle of taxation derived in this section.

4.3 Stylized Facts

4.3.1 Data Sources

We use a commercial database of company accounts, sold under the name Amadeus by Bureau Van Dijk. This commercial database of company accounts is comparable to the Compustat database in the US or the Erstat database in the UK. A growing academic literature uses the Amadeus data, (see Budd et al (2002), Konings et al (2001) and Vandenbusshe and Tan (2005)). We use data for companies in 220 NACE Rev1 manufacturing sectors across France, Italy and UK, during three periods 1996-1998. Companies in the data set have to satisfy at least one of the following criteria: (i) number of employees greater than 100, (ii) total assets exceeding 16 million USD and (iii) operating revenue exceeding 8 million USD respectively. The coverage of medium and large sized enterprises is good in this set of countries. We construct annual measures of effective corporation tax and the HHI of company assets for each NACE sector using, on average, 6,639 French, 7,747 Italian, and 9,077 UK companies.

We measure company size as the value of tangible and intangible fixed assets (in thousands USD). The HHI (Herfindal-Hirschmann Index) is used to measure the concentration of company assets within NACE sectors. We take this to be an outcome of high sector specific sunk costs. Effective corporation tax rate is measured at the overall tax payout over operating revenues (in thousands USD) of each company. Data limitations only allow us to work with the overall tax take and not just the profit tax take. We also prefer to work with a measure of the corporation tax rate as the overall tax payout over operating revenues (in thousands USD), rather than operating profits. We do this for two reasons, tax is overall taxation (not just profit taxation)
and sales are reported better than operating profits with less incentives for creative accounting. The idea is to normalize the tax take by the upper bound on tax revenue for each company. Results are not that different if one wished to use operating profits.

The effective corporation tax rate at the sector level is measured as a weighted sum of company effective tax rates (weighted by the size of company fixed assets). Across sectors differences in effective tax rates result from the different take up of tax allowances, exemptions, and exclusions. Industries with different sunk cost configurations, for example R&D expenditures, have different abilities to benefit from the tax incentives designed by government. Our measure of the effective corporate tax rate reflects such idiosyncratic features of industries (see MARC, (1999), Gropp and Kostial, (2000) for arguments that explain why company level effective tax rates are different and why they should be used in the construction of industry and country level effective tax rates). Murphy (2005) constructs effective tax rates for countries using the Amadeus data and compares them to alternatives measures and data for EU countries. Levels and trends over the 1990s are very similar.

4.3.2 Empirical Results

Our theory predicts that (optimal) effective industry level corporation tax rates should be negatively related to the concentration of assets within industries (proxy for monopolistic power). Using the Amadeus data we aggregate over companies to construct panel data on ECRTR (effective corporate tax rates) and HHI for around 220 4-digit NACE manufacturing industries in France, Italy and the UK. In Figure 4.2 we document industry level effective corporate tax rates relative to the overall manufacturing mean. By normalizing 4-digit NACE manufacturing industries corporation tax rates by the overall manufacturing mean within a country, we see clearly, within each country, the co-existence of low and high effective corporation taxation across industries. Industries with different sunk cost configurations have different abilities to benefit from the tax incentives (allowances, exemptions, and exclusions), designed by governments. In Figure 4.3 we see the spread in the concentration of assets by industry. Industry
structures tend to be highly correlated across countries. Due to industry specific sunk cost configurations rather than from any integration process. The question is, do the sunk cost considerations that drive industry structure also drive the level of effective corporate taxation?

In Table 1 we estimate using OLS and GLS (controlling for sector unobservables, with random effects), that industry level effective corporate tax rates are negatively correlated with the concentration of assets within industries. Even if one runs company level regressions clustered by industry, controlling for company heterogeneity (age, size, ownership), one still finds a significant negative correlation of effective corporate tax rates with industry level concentration. This is clearly suggestive that our Schumpeterian principle of taxation was used across industries within these countries in the late 1990s.

4.4 Conclusions

Using a Sutton (1991) approach to industry evolution, our IO approach links optimal effective corporation tax rates to the nature of sunk costs within industries. Theory predicts that industry level optimal effective corporation tax rates will be negatively related to the concentration of assets within industries. The principle of taxation is very Schumpeterian, driven by a healthy respect of governments for industry dynamics. In our empirical sections we provide suggestive evidence that this principle of taxation was widely used across industries in France, Italy and the UK in the late 1990s.

Our theory could be extended to test the robustness of this principle of taxation. We feel the presence of endogenous sunk costs or rent seeking sunk cost expenditures (allowing companies to move before the government) would not change the government's incentives to tax concentrated industries softly. Open economy considerations such as the intensity of tax competition over investment flows (the design of financing or R&D incentives for multinational corporations) are also likely to be related to the nature of industry specific sunk costs leading to further incentives for governments to tax concentrated industries softly. Even though there
is a large literature on corporation taxation in Public Finance and International trade, we feel it is not a good idea to ignore industry specific effects, in particular the literature on market structure, in the modelling of effective corporate taxation.
Fig. 4.2 Distributions in ECTR across NACE 4-digit industries 1996-1998 relative to 1 (the mean across Time and Country).
Table 1: Correlations between ECTR and HHI across 4-digit NACE industries within France, Italy and UK.

<table>
<thead>
<tr>
<th>ln (ECTR)</th>
<th>France OLS</th>
<th>France GLS</th>
<th>Italy OLS</th>
<th>Italy GLS</th>
<th>UK OLS</th>
<th>UK GLS</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>R²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>11</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Constant</td>
<td>(6.5)</td>
<td>(4.8)</td>
<td>(6.8)</td>
<td>(6.9)</td>
<td>(11.9)</td>
<td>(11.3)</td>
</tr>
<tr>
<td>ln (HHI)</td>
<td>-.38</td>
<td>-.35</td>
<td>-.22</td>
<td>-.21</td>
<td>-.28</td>
<td>-.24</td>
</tr>
<tr>
<td></td>
<td>(6.8)</td>
<td>(5.0)</td>
<td>(6.0)</td>
<td>(4.22)</td>
<td>(3.5)</td>
<td>(2.6)</td>
</tr>
<tr>
<td>Time Dummies</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Random Effects</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td># 4-digit NACE</td>
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<td>227</td>
<td>220</td>
<td>220</td>
<td>223</td>
<td>223</td>
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<tr>
<td># of Observations</td>
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<td>655</td>
<td>662</td>
<td>659</td>
</tr>
</tbody>
</table>

Fig. 4.3 Distributions of HHI across NACE 4-digit industries 1996-1998


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